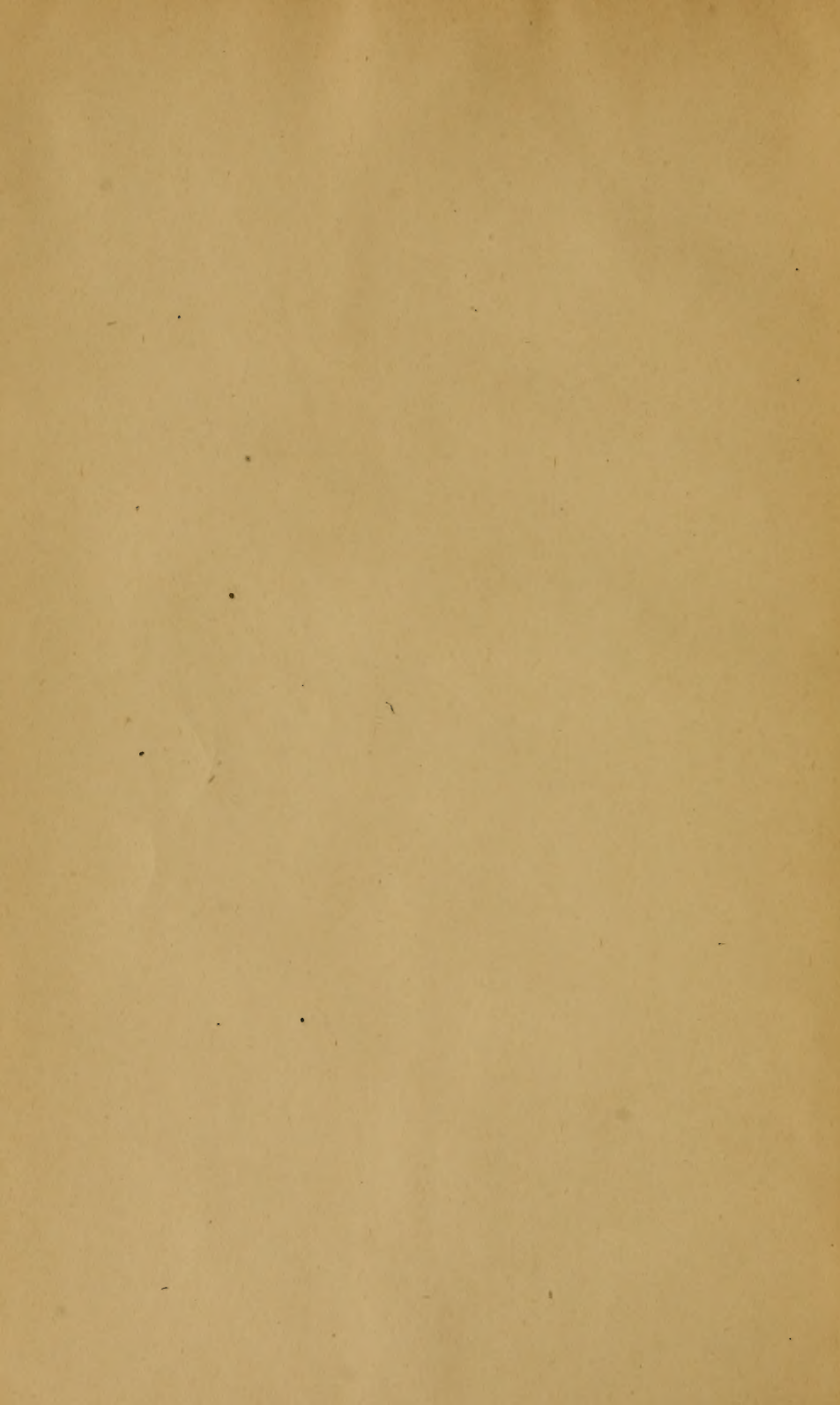




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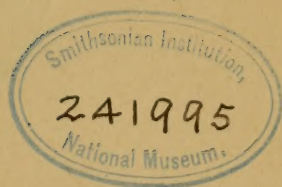




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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 153.

ORCHARD ENEMIES

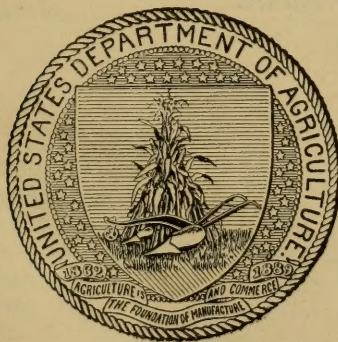
IN THE

PACIFIC NORTHWEST.

BY

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1902.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,

Washington, D. C., April 3, 1902.

SIR: I herewith transmit a manuscript by Prof. C. V. Piper, of the Washington Agricultural Experiment Station, Pullman, Wash., submitted at your request. I have examined the manuscript, and recommend its publication as a Farmers' Bulletin. The portion relating to fungous diseases and the remedies therefor has been approved by the Plant Physiologist and Pathologist.

Respectfully,

L. O. HOWARD,
Entomologist.

Hon. JAMES WILSON,
Secretary of Agriculture.

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ORCHARD ENEMIES IN THE PACIFIC NORTHWEST.

INTRODUCTION.

Within the past ten years the fruit-growing industry in the States of Washington, Oregon, and Idaho has developed very rapidly. With the possible exception of prunes, the greater part of the product is shipped as fresh fruit to Eastern markets, where it has already won a high reputation for quality.

Along with this rapid development of the industry there has been a much more rapid increase in the damage caused by insects and diseases. Ten years ago there was little or no need to fight orchard pests, as the injury caused by them was scarcely appreciable. At the present time, at least in the older sections, the fruit grower is compelled to combat insects or fungi or both, in order to grow marketable crops.

This marked change coming in so short a time, and in many cases involving serious loss, has naturally had a discouraging effect. In a few instances this discouragement has even led to the digging up of orchards. The increase in the amount of damage by orchard enemies has been the more depressing because the idea had gained considerable credence that the previous immunity from such loss was due to some special peculiarity of the soil or climate or both. Unfortunately this idea still prevails in sections where, for some reason or other, pests have not yet become a serious factor. At one time, when western Oregon apples were justly famous, the growers said: "We will never have wormy apples here because the climate is so moist." In the warm interior valleys orchardists now claim that fungous diseases will never be a menace because the climate is too hot and dry; and upon the interior uplands their competitors say that no insect or fungous enemy need ever be feared because of the winds and the cool nights. In all this there is a somewhat labored effort to consider as proven what is at best a hope. The experience of nearly every new region has been much the same. No place has yet been discovered where orchards will thrive where pests will not also thrive. The general truth of the statement is not affected by the well-known fact that the amount of damage caused by a particular insect or fungus varies greatly in different regions and in the same region from year to year.

The rapid spread of certain pests like the codling-moth and apple scab in recent years has led some to the opposite extreme view, namely, that pests are far more injurious here than in other fruit-growing regions. A careful comparison of the loss occasioned here in neglected orchards with similar injury in older States reveals no evidence to justify such a conclusion.

Many orchardists have been slow to adapt themselves to the new conditions caused by the introduction and spread of insects and fungous diseases. Although these new conditions have undoubtedly increased the cost of producing fruit, the growers who have used proper efforts to control insects and disease have been uniformly successful in raising profitable crops of high-grade fruits; on the contrary, the product of neglected orchards is, as a rule, so badly injured that most of it is unmarketable, or must be sold at a very low price.

Serving as object lessons, such results are doing much to increase rational efforts to combat orchard enemies, and undoubtedly the situation will become better from year to year, as the great majority of persons now setting out orchards realize beforehand that it is one of the factors necessary to success.

HORTICULTURAL DIVISIONS.

From a horticultural point of view there are three very distinct regions in the Pacific Northwest. These may be denominated as follows:

- (1) **The Coast Region**, lying west of the Cascade Mountains.
- (2) **The Inland Valleys**, having an altitude of 300 to 1,000 feet, for the most part irrigated, and in which the commercial growing of the peach is carried on.
- (3) **The Inland Uplands**, ranging in altitude from 1,000 to 3,000 feet or more, where commercial peach culture is not practicable.

CONDITIONS AFFECTING ORCHARDS IN THE COAST REGION.

The most striking peculiarities in the region lying west of the Cascades are the very equable mean temperature throughout the year and the rather copious rainfall; periods of drought seldom occur, and then only during a short time in July or August. These conditions, which have favored the heavy forestation of the region, are quite different from those in any other portion of the United States, and have already given rise to a number of new agricultural problems. Only those which particularly concern orchards are discussed here. The humidity of the climate quickly results in trees becoming coated with a growth of lichens, and, later, true mosses, the whole being commonly denominated "moss," which nullifies to a considerable extent the effects of some spraying mixtures; hence, any practice to be completely successful must destroy this moss. Of the spraying compounds,

Bordeaux mixture and the sulphur-salt-lime wash are both efficient for this purpose.

The only practice that has been at all general in orchards here is winter spraying with the sulphur-salt-lime wash. Beyond any question this spray is effective on the Pacific coast against the San Jose scale. It also destroys the eggs of the green aphid and the red spider, and kills moss. It is not effective against the oyster-shell scale, nor, on mossy roughed-barked trees at least, against the woolly aphid of the apple; for apple-scab and blackspot apple canker it is of little or no value. There is no evidence at hand to indicate whether the sulphur-salt-lime wash is at all effective against the brown rot of stone fruits, but it is probably no more efficient for this than for the scab diseases. In view of these facts, winter treatment of trees west of the Cascades with sulphur-salt-lime is unsatisfactory.

The efficiency of this wash seems to depend on the caustic properties of the compounds of lime and sulphur. Its high value here against the scale insects has given rise to the idea that it is a specific against practically all the ills that affect orchard trees, an idea rudely dispelled by the record of actual experiences. As a matter of fact the value of the wash against most fungous diseases seems to be very small and not to be compared with that of Bordeaux mixture.

Up to the present time commercial fruit growing in the coast region has not been a prominent feature of its agriculture. Prune growing is as yet the one phase of fruit production that is conducted on a large scale, and this industry is confined mainly to Clark County, in Washington, and the Willamette Valley, in Oregon. Inasmuch as all stone fruits except the peach do remarkably well, and apples and pears of fine quality can be grown—in fact, fully equal to those of the inland regions—it seems strange that their production on a commercial scale has not been more fully developed. The principal explanation of the failure to do this seems to be the large loss occasioned by scab to the apple and pear, and by brown rot to the stone fruits. To a less degree the black-spot apple canker may have had a like effect. The control of these diseases, however, would seem to offer no more serious problems than do the codling moth and San Jose scale in the inland valleys. Be that as it may, it is certainly desirable that a large additional amount of experimenting be carried on to determine how far these factors are inimical to success. Another factor that may have something to do in limiting commercial fruit growing is the higher initial cost of the land.

A rational treatment for orchard trees in this region may perhaps be made most clear by considering each kind separately.

THE APPLE.

Throughout the coast region, apple-scab and blackspot apple canker cause the most serious losses. It is a conservative estimate that 75

per cent of the apples raised in the region are more or less affected by scab, and but a small portion of the trees are free from the canker.

On the contrary, the loss by insect damage is relatively small. In western Washington not over 10 per cent of the apples are affected by the codling-moth. In the Willamette Valley of western Oregon the same insect causes a loss of from 30 to 60 per cent of the apples, according to Professor Cordley.

An unimportant amount of damage is caused by the wooly aphid and by the oyster-shell scale, or bark louse. The San Jose scale is very rare in western Washington and by no means a serious factor in western Oregon.

An insect recently introduced from Japan, the apple fruit miner (*Laverna herellera*), may become a serious pest. As yet it is not widespread, and so little is known of its life history that no method of treatment can be recommended. It may easily be known by the sinuous passages bored through the fruit by the larvæ.

The control of fungous diseases in the coast region is rendered difficult owing to the frequent rains, especially those of spring and early summer. In the case of apple scab the two or three sprayings of Bordeaux mixture usually recommended are not sufficient. Five sprayings is probably the smallest number necessary to insure good results. In the light of present experience these are best applied as follows: The first, just before the flower buds open in spring; the second, just after the blossoms fall; the third, 10 to 12 days later; the fourth and fifth, at intervals of two weeks. The last two sprayings should be with ammoniacal copper carbonate, as the Bordeaux mixture causes fruit to russet, especially when damp weather follows the spraying. There is still need that much experimental work be done on this disease under the peculiar conditions existing, as it is much the worst enemy the apple grower has to contend with. The above suggestions are admittedly based on too meager a series of experiments.

The disease here designated blackspot apple canker, also known as "blackspot," "deadspot," "apple anthracnose," and "apple canker," is a serious enemy, especially of young apple trees. A detailed account of the disease and of the methods for controlling it is given farther on.

Where the average loss by the codling-moth is 10 per cent or less, it is a comparatively unimportant factor. It seems desirable, however, to add Paris green to the third spraying of Bordeaux mixture, 1 pound of the poison to each 150 gallons of liquid. Where, as in the Willamette Valley, the loss is greater, one or perhaps more additional sprayings with Paris green are necessary.

For the wooly aphid, summer sprayings of kerosene emulsion, 1 part to 12 parts water, have given very satisfactory results. In western Washington, at least, the root form seems not to occur.

THE PEAR.

Pear scab is the most serious disease yet affecting this fruit in the Coast region. It requires the same treatment as apple scab.

Blight, or "fire" blight, of the pear is yet unknown in western Washington, but it is reported from western Oregon. In view of the enormous damage this disease has caused in the inland regions, it is very desirable to prevent its spread as much as possible.

The pear-leaf blister-mite is of frequent occurrence.

THE CHERRY.

Brown rot, or fruit mold, is the only disease of serious consequence. The control of this disease is difficult, but two sprayings of Bordeaux mixture seem decidedly helpful. One of these should be just before the flowers open, the other immediately after the petals fall. It is decidedly helpful to prune the trees so that the tops are open and the fruit exposed as much as may be to the sunshine.

Of insects, the black aphid is periodically abundant. It can easily be destroyed with kerosene emulsion.

Gummosis, a disease of very obscure origin, is a frequent trouble with sweet cherries. Nothing satisfactory can be recommended in the way of treatment. The common practice of slitting the bark is, at best, of doubtful value. Trees grafted on wild stock are somewhat less subject to the disease.

THE PLUM AND THE PRUNE.

Like the cherry, both of these fruits are subject to the brown rot. While the disease varies greatly in severity from year to year, the gathering and burning of the mummified fruits should never be neglected. The thinning of the fruit so as to prevent clusters is also desirable. Spraying for this disease has given contradictory results, and much experimenting is yet necessary to determine whether it is profitable or not.

The peach-tree borer is prevalent in some sections, attacking particularly prune trees grafted on peach roots. Digging out the larvae in fall and spring with a knife is the usual method of control. In addition some growers mound up earth about the bases of the trees in May, a practice which would seem to be always desirable, and perhaps as good as any that can at present be recommended.

In the last few years the root disease caused by the mushroom, *Armillaria mellea*, has been prevalent in Clark County, Washington. Apparently it has been introduced, as it has not been found in adjacent woodlands. Besides the mushrooms which appear about the bases of the affected trees in the fall, the disease may be known by the black, string-like strands (rhizomorphs) which occur on the crown and roots.

These rhizomorphs are part of the vegetative body of the mushroom. The disease spreads by the spores produced on the mushrooms and by the rhizomorphs which grow along the roots of the affected trees and thus reach adjoining trees. No remedy is known for the disease, which is nearly always fatal, at least to prunes. The only real method of control is to dig up the affected trees, roots and all, and burn them. No new trees should be planted in the same spots for several years. An affected tree, if not at once dug up, should be isolated from adjoining trees by a ditch a foot wide and two feet deep. In any case the mushrooms should be gathered and destroyed when they appear. This particular kind is edible. Some growers have tested the efficacy of lime, placing it in considerable quantity about the roots of an affected tree, and it is claimed that in some cases the trees recovered. There is room for considerable investigation in testing the usefulness of lime, of Bordeaux mixture, and of other substances in this manner, though the chances are that none of them will prove satisfactory remedies.

In addition to the above, the prune especially is subject to two obscure ailments which are not caused by either insects or fungi. One of these is called "leaf curl," and is characterized by the leaf margins rolling in loosely toward the midrib, and usually becoming more or less yellowish. In bad cases many of these leaves fall off, and sometimes, at least, many of the prunes as well. The trouble usually occurs in July and August and seems due primarily to drought. At least it is common to see it in some orchards while absent from adjoining ones; and, in the same orchard, it may frequently be noticed that the trees in moister situations are normal in their appearance while the rest are affected by the "curl." This view is held by many orchardists, and the fact that the prune is thus affected in every part of the Northwest where it is cultivated lends considerable weight to the conclusion.

It is a noticeable fact, however, that some individual trees are more subject to the trouble than others. Where this is the case it is usually easy to find some secondary cause, such as injury to the crown by borers or by the mushroom disease, partial girdling due to the bark bursting, or an imperfect union of the scion and stock.

The other trouble is locally known as bark bursting, and seems confined to the Coast region. It was particularly prevalent in 1899. It is characterized by the splitting of the bark in an irregularly longitudinal direction, and not rarely being torn away from the wood for some distance on each side of the split. So far as observed, this occurs only in late winter or just before the buds burst in spring.

A current idea in regard to the trouble is that it results from the tree being bark bound, and a common practice based on this idea is to slit the bark from the branches to the ground. It is also claimed that leaf curl is a result of the tree's being bark bound and that the slitting

process releases the pressure of the bark so that the sap can flow more freely. The bark binding is supposed to result from the wood and inner bark growing more rapidly than the tough outer bark, the strain finally becoming so great that the bark bursts and even breaks away from the wood. To all of the above views there are vital objections. The supposition that bark binding interferes with the sap flow and thus causes leaf curl may be dismissed as absurd, for it is impossible for the bark to exert pressure enough to prevent the upward movement of water in the sapwood. It is also a fact that the bursting does not take place when the wood growth is greatest and the stretching of the bark most intense. On the contrary, it takes place, if at all, near the close of the winter season, when there is absolutely no growth.

That the bursting could be caused by low temperature alone seems out of the question, as in the coast region the winter temperature is so high that skating is a rare sport, and only twice in twenty years has the thermometer registered zero. In the inland areas much lower temperatures occur, but bark bursting is there unknown.

With our present knowledge of the trouble no adequate explanation can be given. It has been suggested that root pressure may have something to do with the phenomenon. The conditions in winter in the coast region are frequently such that the roots may be active in the relatively warm soil long before any leaves have developed in the branches. This would result in a considerable sap pressure within the tree, but it seems hardly probable that it could be great enough to burst the bark, even in case of a sudden drop in the temperature. Whatever the cause, the best remedy is to bind the bark at once, using a liberal supply of grafting wax of some sort to keep out fungus spores. The binding should be done with strips of cloth or burlap, which should be tightly drawn. If this is done promptly the wound will heal over nicely.

Slitting the bark is of doubtful value. However, it can do little harm, even if it does no good.

CONDITIONS AFFECTING ORCHARDS IN THE INLAND VALLEYS.

The Cascade Mountains separate two regions widely different in soil and climate. On the one side these have fostered the development of great forests; on the other almost antithetical conditions have resulted in the plains and hills being practically treeless. While the coast region has an abundant rainfall and no great extremes in temperature, the inland region, in many parts at least, has an insufficient rainfall and the extremes of heat and cold are more marked.

In the fruit-growing districts of the inland region there are well-marked differences between the valleys, where for the most part irrigation is practiced, and the uplands, where rainfall must be depended on.

The valleys here considered are those which lie at an altitude of 300 to 1,000 feet above the sea level, including practically all of the regions in which the peach thrives, and which in the main are cultivated under irrigation. In these valleys commercial fruit growing is, perhaps, more extensively engaged in at present than anywhere else in the Pacific Northwest.

The extremely favorable conditions, so far as pests are concerned, in these inland valleys lies in the absence of any serious fungous disease. Apple and pear scab do not occur; brown rot is reported from but one locality; blackspot canker is unknown. How far these conditions are due to climate, and how far to comparative isolation, is difficult to determine. The experience of most of the older fruit-growing communities is a warning to the fruit grower that there is little ground for hope of immunity from any particular pest on account of climatic influences. The absence of such serious enemies as peach yellows, brown rot, and plum curculio, not to mention others, is an important factor in successful orcharding in these valleys.

INSECT ENEMIES.

The following are the insect pests of most importance:

San Jose scale.—The first appearance of this insect in the Northwest seems to have been in the Snake River Valley, at Almoda. At the present time the insect is abundant in most of the valleys and occasional on uplands. The universal practice is to spray in winter with the sulphur-salt-lime wash, which is completely effective when properly applied. Excepting that such winter applications entail a perennial expense, the advent of the insect has caused little damage. An incidental feature gained in peach orchards by these winter sprayings is the control of the peach-leaf curl, which occasionally caused considerable damage.

Codling moth.—Taken all in all this is the worst insect pest in the Northwest, and it is more destructive in these inland valleys than elsewhere. Owing to the long warm season, the insect may be found at almost any time, and in all stages, from May to September. It is commonly believed that in these valleys the insect has three or more annual broods, but this is by no means demonstrated. The experience of fruit growers has led them to spray from five to seven times each season to control this insect. The majority of orchardists use Paris green, but others secure as good results apparently with the cheaper arsenite of soda mixture. The sprayings as carried out by most growers are as follows: The first, just as soon as the petals fall; the second, two weeks later; the third, about July 10, and the remaining sprayings at intervals of two to three weeks, the last one being in September. A few growers supplement their spraying with the "banding system," and believe that the results secured justify the practice.

Aphides or plant-lice.—In some sections these are occasionally very abundant, especially those of the apple and plum. Kerosene emulsion is generally used to keep them down.

Peach moth or peach twig-borer.—This insect was abundant in 1897 and again in 1900 and 1901. Winter sprayings with kerosene emulsion as determined by experiments on Snake River are very effective. The sulphur-salt-lime wash seems to have no effect on the insect.

BACTERIAL AND FUNGOUS DISEASES.

Peach mildew (*Sphaerotheca pannosa*).—This disease is of general occurrence in peach orchards, but does comparatively little damage. Some years the disease is excessively abundant and other years scarce. I have never been able to detect any other reproductive organs than the conidia or summer spores. The fungus lives over winter on young twigs.

Up to the present time the disease has received no specific treatment, and, in view of the relatively small damage done, it is probably not profitable to spray against it.

Pear blight.—This disease has been extremely destructive in almost every part of the inland region for three years past. It is estimated that 70 per cent of the pear trees in the region are either killed or so badly injured as to be of little value. Some varieties have withstood the disease much better than others, but strangely enough the same variety seems to differ in its degree of resistance in different localities.

CONDITIONS AFFECTING ORCHARDS IN THE INLAND UPLANDS.

By the uplands are meant the valleys and rolling hills having an elevation of from 1,000 to 3,000 feet. In general, such lands comprise the wheat-growing area of the inland region. Dependence is placed entirely upon the rainfall, which in some localities is barely sufficient to insure a crop. In wheat raising, indeed, the most common practice is to summer fallow the land each alternate year, and in the drier localities this is necessitated by the scanty rainfall. During recent years a great acreage of fruit trees has been planted in such lands, and the hardier fruits have proven very satisfactory investments.

INSECT ENEMIES.

Thus far there has been but very slight damage from insect pests. How much this is due to the relative newness and isolation of the orchards, and how much to the climatic conditions, it is difficult to determine. The following notes on such insects and diseases as have already appeared give the only indications we have as regards their probable future behavior:

Codling moth.—In the past four or five years the average damage caused by this insect has been less than 10 per cent. It is generally thought that this low percentage of damage is due to the cool nights of the region, to some extent aided by the prevailing fresh winds. Inasmuch as the damage occasioned by this insect in Snake River Valley is always large, while on the uplands 2,000 feet higher and only 1 to 3 miles distant the loss is nearly always small, considerable weight is given to this opinion. Nevertheless in occasional orchards in the uplands the loss has in certain years, notably 1898, reached as high as 25 and even 40 per cent. This is commonly ascribed to the peculiarities of the particular season, which may be the true explanation; but in view of the newness of the orchards it can not be considered as demonstrated.

San Jose scale.—Up to four years ago this insect was not known to occur in the interior uplands, and it was generally believed that it could not thrive there. Its occurrence in at least 4 orchards located at an altitude of about 2,000 feet has dispelled this notion. In each case, however, the spread of the insect in the orchard has been very slow, so that but little damage has been caused though no attempt has been made to destroy it. These facts would seem to point strongly to the conclusion that outside of the peach-growing districts the San Jose scale is not likely to prove a serious menace. In every case, however, no pains should be spared to exterminate the insect, and this, by hard pruning and thorough spraying, can be accomplished. It is far more economical to exterminate the insect, if possible, than to be compelled to spray for it every year or two.

BACTERIAL AND FUNGOUS DISEASES.

Pear blight.—This terrible disease has been very destructive in the past three years, from 60 to 80 per cent of the pear trees in the region having been practically destroyed. Quince trees, too, have suffered severely, but apple trees have scarcely been affected. In view of the highly destructive character of this disease, the future of pear culture in the Northwest is very uncertain.

Apple scab.—Of the lands here called the inland uplands, the greater portion is treeless prairie. To the northward and eastward, however, the prairies merge into the forest-clad foothills of mountain ranges, where the rainfall is somewhat greater. In these forested regions, especially in northern Idaho, the apple scab has been more or less prevalent for several years past, the amount of the damage varying in different seasons. On the adjoining prairie regions the disease seems to be spreading slowly, but until now not 2 per cent of the apples have been affected. Outside of the forest belt, at least, the present experience would indicate that the disease is not apt to become an important factor.

LEGISLATION.

While differing considerably in character, the horticultural laws of Oregon, Washington, and Idaho aim to prevent the introduction and to control the spread of injurious insects or diseases by all practicable means, namely: Nursery stock inspection, quarantine of suspected fruit, and compulsory treatment of infested orchards.

NURSERY-STOCK INSPECTION.

Perhaps more attention has been given to this phase of the horticultural laws than to any other. Unquestionably the effect has been to make nurserymen much more careful regarding the quality of the nursery stock they ship. Without doubt, too, this inspection has to some degree limited the spread of well-known insects and diseases. It is very probable, indeed, that the cost of the service is more than repaid by the benefits derived. But as a means of preventing the introduction of new pests, nursery-stock inspection has not succeeded.

With the exception of a very few dangerous insects and diseases, among them peach yellows and plum curculio, practically every serious orchard pest is now known to occur in the Northwest. It may be, and probably is, the fault of an imperfect service rather than of the method, but the fact remains that the wished-for result was not attained, and, of course, is not now attainable.

QUARANTINE OF INFESTED FRUIT.

In the enforcement of this phase of the horticultural laws, the exercise of a certain discretion is noticeable. In few, if any, cases have domestic fruits infested or injured by apple scab, codling moth, or peach moth been quarantined. On the contrary, when infested with San Jose scale, they have usually been quarantined and condemned. Imported fruit, as a rule, is subjected to much stricter quarantine than is domestic fruit. In numerous cases infested oranges and lemons have been quarantined and the owners compelled to fumigate or destroy them. The apparent object of this is not to protect orchards, as they are in nowise threatened by such insects, but to discourage shippers and importers from handling such infested fruit. In so far as imported fruits are of the same sorts as domestic, it is certainly desirable that the quarantine laws be strictly enforced, especially as regards Japanese fruits. The introduction of the apple fruit-miner through that source is an object lesson that should be heeded. As was pointed out in the Yearbook of the Department of Agriculture for 1897 by Dr. L. O. Howard, there are a number of Japanese insects which, if introduced, are likely to become serious pests.

COMPULSORY TREATMENT OF INFESTED ORCHARDS.

The general enforcement of horticultural laws of this class is attended with difficulty. The actual inspection of every orchard in the State demands an amount of work that the service provided does not succeed in accomplishing. While undoubtedly the most direct means of controlling pests, its efficiency would probably be increased by limiting the number of insects or diseases whose control is attempted. The sentiment seems to be growing among orchardists in the Northwest that every means, including compulsory treatment, should be enforced to control insects or diseases that injure or destroy orchard trees; that this is more important than to expend the necessarily limited energy of the officials in combating pests that affect merely or mainly the fruit. It is objected by some that it is practically impossible to compel an unwilling person to carry out any compulsory treatment properly, and by others that, even if compulsory treatment for such pests as codling moth and apple scab is enforced, it will not to an appreciable degree make it cheaper for orchardists in general to raise first-class fruit. In short, it is argued that the law can not be fully enforced, and that it makes very little difference if it is. But these difficulties remain whether we consider only tree-injuring or only fruit-injuring pests. After all, the exercise of wise discretion on the part of the officers of the law would seem to be necessary. In any case it would seem wise to endeavor to prevent the spread of a new disease or insect as much as possible. So far as well-established enemies are concerned, it would appear to be wisest to enforce the law only where there is a reasonable hope of exterminating them or confining their spread.

INSECTICIDES AND THEIR PREPARATION.

Two general classes of insecticides are commonly used in spraying, namely, those which kill by external contact and those which kill by internal poisoning. The former are used almost exclusively against such insects as plant lice and scale insects, which obtain their nourishment from the plant by means of sucking beaks. The latter are useful only against insects which obtain their food by biting or gnawing.

Attention to these fundamental differences will prevent the mistake too frequently made of spraying with Paris green or similar poisons for such insects as plant lice or the San Jose scale.

Of contact or external insecticides the most important to the Pacific Northwest are the sulphur-salt-lime wash, kerosene emulsion, and whale-oil soap with or without quassia.

Of internal poisons the arsenicals only are used, Paris green being the most common. Paris green is sometimes adulterated, and this, in part at least, accounts for some complaints of nonsuccess attending its use. To be sure that the article purchased is reliable, it is

always well to send a small sample to the chemist of the State experiment station to report upon it.

Recently the arsenic and lime and the arsenic-soda-lime mixtures have been employed by some fruit growers, who report excellent results. Both of these, being cheaper than Paris green, deserve trial, and formulas are therefore given.

THE SULPHUR-SALT-LIME WASH.

Good lime	pounds..	40
Sulphur	do....	20
Salt	do....	15
Water to make	gallons..	60

Take 10 pounds of lime and 20 pounds of sulphur, boil with 20 gallons of water for about two hours, or until the sulphur is thoroughly dissolved and the mixture is of deep amber color. While boiling, the liquid must be stirred frequently. Next, place in a cask the rest of the lime and pour enough hot water over it to thoroughly slack it, and while it is still boiling add the salt and stir until it is thoroughly dissolved. Then add this to the lime and sulphur solution in the boiler and boil for another hour. Sufficient water to make 60 gallons should then be added, keeping the mixture well stirred meanwhile. As the solution must be kept well stirred when spraying, it is best to use a pump with an agitator.

This spray is to be used only in the winter, when the leaves are off the trees, and is most effective when applied hot. The trees should first be well pruned, and the spray applied thoroughly, care being taken that no part of the tree, not even one of the smallest twigs, does not receive its coating of the wash.

This is the standard winter wash on the Pacific coast for the San Jose scale. It will also destroy the eggs of the green aphid and the red spider. As a fungicide the mixture has but small value. Some orchardists add concentrated lye to the above solution in the proportion of 2 or 3 pounds to the hundred gallons, claiming that the wash is made much more effective thereby. As it is completely effective without the lye, the addition of the latter seems unnecessary, and no careful experiments have yet been made which demonstrate that the lye is a desirable addition.

The formula as above given is the standard one as at present used. In its manufacture some orchardists slake all the lime, adding the sulphur and salt immediately, and then boil for three hours. There appears no reason to believe that the resulting compound is any different from that obtained by the ordinary method.

Up to the present very little experimenting has been carried on to determine whether modifications of this wash are as effective or more

effective, and there is room for much investigation in this direction. The modification known as Oregon winter wash, in which bluestone is used to replace the salt, has been somewhat extensively used. This was supposed to be virtually a mixture of sulphur-salt-lime and Bordeaux, but chemically, at least, it is not. Theoretically, it would seem that an actual mixture of the two sprays would be better. In places where it is necessary to spray for both the apple scab and the San Jose scale, a series of experiments to test the double efficacy of such a mixture is desirable. Where the San Jose scale occurs, present experience indicates that sulphur-salt-lime is the best spray. Where a fungus alone is sprayed for, Bordeaux is probably the best fungicide.

KEROSENE EMULSION.

Kerosene.....	gallons..	2
Whale-oil soap (or 1 quart soft soap).....	pound..	$\frac{1}{2}$
Water	gallon..	1

Dissolve the soap in the boiling water and while still hot add to the kerosene, taking care to keep the latter away from the fire. The whole mixture is then violently agitated, preferably by being pumped back on itself through an ordinary one-eighth-inch nozzle. Many forms of spray pumps answer the purpose admirably. After four or five minutes pumping the mixture will have a thick creamy consistency, and if well made will stand indefinitely without free oil rising to the surface.

One quart of soft soap may be used instead of the one-half pound of hard soap.

Unless otherwise stated, the emulsion is to be used dissolved in water in the proportion of 1 gallon of the emulsion to 15 to 20 gallons of water.

PARIS GREEN OR LONDON PURPLE.

Paris green or London purple	pound..	1
Lime.....	do.....	1
Water	gallons..	150

Make a fine paste of the Paris green or London purple with a small quantity of water, and then add to the lime which has been slaked in a bucket. Pour the mixture through a strainer into the spray tank and add the water.

In some cases, notably for cabbage worms, the poison is better applied dry. For this purpose 1 pound of the poison is mixed with 50 pounds of flour, air-slaked lime, or dust, care being taken to make the mixture very thorough. This is to be applied to the plants, preferably in the early morning, when they are wet with dew. It may be dusted on by sifting through a piece of coarse cheese cloth, or by means of special apparatus made for the purpose.

ARSENIC AND LIME.

White arsenic.....	pound..	1
Lime	pounds..	2
Water.....	gallons..	2

Boil the above ingredients for three-fourths of an hour. For use, dilute by adding 300 to 400 gallons of water.

Additional lime in the solution may be necessary to prevent burning of the foliage.

ARSENIC, SODA, AND LIME.

White arsenic.....	pound..	1
Sal-soda crystals.....	pounds..	4
Water	gallons..	2

Boil the above ingredients for fifteen to twenty minutes, when the arsenic should be dissolved, leaving only a little sediment. This stock solution may be kept indefinitely, but should be labeled "poison."

To prepare the spraying mixture add 1 quart of the stock solution to 40 gallons of water in which 2 pounds of fresh lime has been dissolved.

Another formula which has been much used by some orchardists, notably, Hon. E. L. Smith, of Hood River, Oreg., is as follows:

White arsenic.....	pound..	1
Sal soda ^a	pounds..	2
Water.....	gallons..	2

To prepare the spraying mixture, slake 6 to 8 pounds of lime in 50 gallons of water. Add to this $1\frac{1}{2}$ pints of the stock solution, stir thoroughly, and the mixture is ready for use. The results are claimed to be fully equal to those attained with Paris green.

In employing either of these formulas use great care. The pots and utensils used in preparing the solution should not be employed for other purposes. The arsenic should be plainly labeled, lest it be mistaken for something else.

WHALE-OIL SOAP AND QUASSIA.

Quassia chips.....	pounds..	8
Whale-oil soap.....	do.....	7

Soak the chips twelve hours in 8 gallons of water. Dissolve the soap in boiling water. Strain the quassia extract to remove the chips and add the soap solution. Stir thoroughly and dilute to make 100 gallons.

^aThe dry sal soda should be used in this formula. If the crystal sal soda is used some of the arsenic will remain free and may burn the foliage, as 1 pound of arsenic combines with 1.6 pounds of dry sal soda, or 4.4 pounds of the crystal sal soda. If the crystal sal soda is used it should be increased to 4 pounds, or the spraying mixture should stand for an hour or two in order to allow the arsenic to combine with the excess of lime.

This solution is used almost exclusively for the hop aphid. It is quite as effective against other species of aphids.

The whale-oil soap without the quassia is of somewhat less efficiency.

FUNGICIDES, AND HOW TO PREPARE THEM.

Fungicides are mainly preventive in their effects, a fact that should never be forgotten. Their beneficial action is to prevent the growth of the fungus and the germination of the spores. When the fungicide has been washed off by rain or otherwise removed, the prompt appearance of the fungus may be expected, as rarely or never are the spores destroyed. The most important fungicides are sulphur and its compounds, and the copper salts. In orchard operations sulphur is used mainly for the grape mildew, ordinary commercial sulphur being dusted on the vines. Of the copper sprays, Bordeaux mixture is by far the most important and practically the only one employed in the Northwest.

The following description of methods to be used in preparing fungicides is quoted from Farmers' Bulletin No. 38, Spraying for Fruit Diseases, prepared by B. T. Galloway, of the U. S. Department of Agriculture:

BORDEAUX MIXTURE.

All things considered, it is believed that the best results will be obtained from the use of what is known as the 50-gallon formula of this preparation. This contains—

Water	50 gallons.
Copper sulphate.....	6 pounds.
Unslacked lime	4 pounds.

It has been found that the method of combining the ingredients has an important bearing on both the chemical composition and physical structure of the mixture. The best results have been obtained from the use of the Bordeaux mixture made in accordance with the following directions: In a barrel or other suitable vessel place 25 gallons of water. Weigh out 6 pounds of copper sulphate, then tie the same in a piece of coarse gunny sack and suspend it just beneath the surface of the water. By tying the bag to a stick laid across the top of the barrel no further attention will be required. In another vessel slack 4 pounds of lime, using care in order to obtain a smooth paste, free from grit and small lumps. To accomplish this it is best to place the lime in an ordinary water pail and add only a small quantity of water at first, say a quart or a quart and a half. When the lime begins to crack and crumble and the water to disappear, add another quart or more, exercising care that the lime at no time gets too dry. Toward the last considerable water will be required, but if added carefully and slowly a perfectly smooth paste will be obtained, provided, of course, the lime is of good quality. When the lime is slacked add sufficient water to the paste to bring the whole up to 25 gallons. When the copper sulphate is entirely dissolved and the lime is cool, pour the lime milk and copper sulphate solution slowly together into a barrel holding 50 gallons, as shown in figure 1. The milk of lime should be thoroughly stirred before pouring. The method described insures good mixing, but to complete this work the barrel of liquid should receive a final stirring, for at least three minutes, with a broad wooden paddle.

It is now necessary to determine whether the mixture is perfect—that is, if it will be safe to apply it to tender foliage. To accomplish this, two simple tests may be

used. First insert the blade of a penknife in the mixture, allowing it to remain there for at least one minute. If metallic copper forms on the blade, or, in other words, if the polished surface of the steel assumes the color of copper plate, the mixture is unsafe and more lime must be added. If, on the other hand, the blade of the knife remains unchanged, it is safe to conclude that the mixture is as perfect as it can be made. As an additional test, however, some of the mixture may be poured into an old plate or saucer, and while held between the eyes and the light the breath should be gently blown upon the liquid for at least half a minute. If the mixture is properly made, a thin pellicle, looking like oil on water, will begin to form on the surface of the liquid. If no pellicle forms, more milk of lime should be added.

If spraying is to be done upon a large scale, it will be found much more convenient and economical in every way to prepare what are known as stock solutions of both the copper and lime. To prepare a stock solution of copper sulphate, procure a barrel holding 50 gallons. Weigh out 100 pounds of copper sulphate, and after tying it in a sack suspend it so that it will hang as near the top of the barrel as possible. Fill the barrel with water, and in two or three days the copper will be dissolved. Now remove the sack and add enough water to bring the solution again up to the 50-gallon mark, previously made on the barrel. It will be understood, of course, that this



FIG. 1.—Making Bordeaux mixture; Pouring together the lime milk and copper sulphate solution.

second adding of water is merely to replace the space previously occupied by the sack and the crystals of copper sulphate. Each gallon of the solution thus made will contain 2 pounds of copper sulphate, and, under all ordinary conditions of temperature there will be no material recrystallization, so that the stock preparation may be kept indefinitely.

Stock lime may be prepared in much the same way as the copper sulphate solution. Procure a barrel holding 50 gallons, making a mark to indicate the 50-gallon point. Weigh out 100 pounds of fresh lime, place it in the barrel, and slack it. When slacked, add sufficient water to bring the whole mass up to 50 gallons. Each gallon of this preparation contains, after thorough stirring, 2 pounds of lime.

When it is desired to make Bordeaux mixture of the 50-gallon formula it is only necessary to measure out 3 gallons of the stock copper solution, and, after thorough stirring, 2 gallons of the stock lime; dilute each to 25 gallons, mix, stir, and test as already described. One test will be sufficient in this case. In other words, it will not be necessary to test each lot of Bordeaux mixture made from the stock preparations, provided the first lot is perfect and no change is made in the quantities of the materials used. Special care should be taken to see that the lime milk is stirred thoroughly each time before applying. As a final precaution it will be well to keep both the stock copper sulphate and the stock lime tightly covered.

AMMONIACAL SOLUTION OF COPPER CARBONATE.

This preparation, as now generally used, contains—

Water	45 gallons.
Strong aqua ammonia.....	3 pints.
Copper carbonate.....	5 ounces.

The copper carbonate is first made into a thin paste by adding a pint and a half of water. The ammonia water is then slowly added, and if of the proper strength, i. e., 26 degrees, a clear, deep-blue solution is obtained, which does not become cloudy when diluted to 45 gallons.

The ammoniacal solution of copper carbonate being a clear liquid, its presence on the leaves, fruit, and other parts of the treated plants is not so noticeable as where the preparations containing lime are used.

In case it is desired to keep the strong solution as a stock preparation, the bottle or jug in which it is placed should be tightly corked.

In spraying the apple and pear for codling-moth and scab, time and expense may be saved by combining the sprays. In this case Paris green is added directly to the Bordeaux, using 1 pound of the poison to 150 gallons of the Bordeaux; but of course the Paris green is not to be used with the Bordeaux in the sprayings which are applied before the trees blossom.

The arsenic-lime and arsenic-soda-lime compounds may be used in the same way. In making such spraying mixtures, the Bordeaux solution is always to be considered as replacing the water, in making calculations.

QUACK INSECTICIDES AND FUNGICIDES.

There are always upon the market various sorts of patent spraying compounds and nostrums, which agree in one respect only, and that is in being recommended as a perfect remedy for every insect and fungus that ever attacks plants.

While several of these compounds have more or less merit, none of them thus far tested are equal to the standard sprays. For the most part they are decidedly more costly and decidedly less effective.

Two classes of these compounds need especial mention and condemnation:

CURE-ALL REMEDIES.

These are mixtures of almost every conceivable substance that has ever been used with the slightest degree of success. One such has been advertised as containing whale-oil soap, arsenic, copper sulphate, tar, green vitriol, and sulphur, but as a matter of fact some of these were not present. A vital objection to such "shotgun" remedies, even if they possess real merit, is their greater cost. Anyone can see that when arsenic is the desired insecticide the others are useless, and the same might be said of nearly every ingredient in turn. The idea of the manufacturer seems to be that the average farmer has not intelligence enough to make standard sprays, and hence is glad to

purchase one that can be used against every enemy which may attack his trees. The apparent commercial success of some of these manufacturers seems to show that the farmer, like most of his fellows, needs to be warned against humbugs.

SAP POISONS.

An enticing idea to everyone that owns a tree is that it may be made immune to insects and fungi by putting some compound at its roots, or preferably in a hole bored in the trunk. Copper sulphate, either alone or mixed with other substances, seems to be a favorite remedy with people who accept the idea. Recently a mixture of this sort has been widely advertised. On analysis it was found to contain copper sulphate, bone charcoal, sulphur, and some washing powder. The charcoal and sulphur, which are insoluble in water, made up most of the mixture.

The theory of such remedies is to poison the sap of the tree so that insects will either be poisoned by it or else dislike its taste, and fungi will be unable to thrive on account of it. The unfortunate flaw in the theory is that copper sulphate is quite as poisonous to the trees as it is to the pests, and a sufficient quantity of it to have the desired effect would result disastrously to the tree.

Faith in these supposed remedies would be largely destroyed if farmers would test them impartially. For example, in a horticultural meeting not long since a farmer declared that copper sulphate placed at the roots of young trees protected them from aphid attacks. He had treated thus every tree in his orchard the year before, and not one was attacked by that insect, which proved to him that the copper sulphate repelled the aphides. As a matter of fact, it did not prove this. The thing was just as well and probably more truly explained by its not being an "aphid year." If the farmer had treated all his orchard save a series of check trees here and there throughout the orchard, and the check or untreated trees had been attacked, while the treated trees were free from the insect, he would have had strong evidence in favor of the truth of his idea. Without such check trees by which to compare results, any series of experiments is of little value, because the results can not be clearly interpreted. If farmers would bear this fundamental part of every experiment in mind, there would soon be less success too in the quack insect-destroyer business.

INSECT PESTS.

In the following paragraphs the principal insects affecting orchards in the Pacific Northwest are briefly described, their habits are outlined, and the proper remedies are named:

SAN JOSE SCALE.

So well known has this destructive insect become that most orchardists are familiar with it. Its presence in an orchard is usually first

discovered during fruit picking. On apples and pears especially the presence of the scale is at once disclosed by the bright red ring-like spots which surround the places where the scales are attached to the fruit. No other scale insect does this; so that this peculiarity makes identification easy and certain. Red spots sometimes appear on fruit from other causes, but in such cases, of course, no scale insect will be found at the center. This fact is an important one, because it enables a fruit grower to discover promptly not only when his orchard becomes infested, but the exact trees which are attacked.

When the scales are abundant they completely cover the trunk and branches, giving them a characteristic grayish mealy appearance. On scraping such a twig a yellowish oily fluid will be seen, which comes from the crushed bodies of the insects. Cutting a strip of the bark will reveal a reddish discoloration, which may also extend to the wood.

The San Jose scale is at once distinguished from other related pests by the small size of the scales, which measure commonly about one-sixteenth of an inch in diameter, though rarely specimens may be found nearly an eighth of an inch across. The scales are circular and somewhat elevated in the middle, which bears a small black or yellowish pointed process. In badly infested orchards they completely cover the trees, giving the branches an unhealthy, grayish, scurfy appearance.

In winter the scales are to be found only in half or nearly full grown condition, and completely dormant. With the first flow of sap in spring they begin to feed again, and become fully grown in May and June, when the first brood of larvæ is produced. So far as known, all these larvæ are born alive. They move about actively for a few hours or even a day or more, finally settling on tender twigs, leaves, or fruit, into which they gradually insert their beaks and begin to suck juices from the plant.

From this time on broods are produced incessantly through the summer, and the insect can be found in all stages until late in October. Shortly after settling on a spot the larva secretes a waxy substance, the beginning of the formation of a scale.

Description.—The following description is quoted from Dr. L. O. Howard, Entomologist, U. S. Department of Agriculture:

In two days the insect becomes invisible, being covered by a pale grayish-yellow shield, with a projecting nipple at the center. This nipple is at first white in color. Twelve days after hatching the first skin is cast. The males at this time are rather larger than the females, which have large purple eyes, while the females have lost their eyes entirely. The legs and antennæ have disappeared in both cases. Six days later the males begin to change to pupæ, while the females have not yet cast their second skin. At this time the females are so tightly cemented to the scale that they can not be removed without crushing. In two or three days more, or twenty to twenty-one days after hatching, the females cast their second skin, which splits around the margin of the body. At twenty-four days the males begin to issue,

emerging from the scales as a general thing at night. At thirty days the females are fully grown, and embryonic young can be seen in their bodies, and from thirty-three to forty days the larvæ begin to make their appearance.

The adult male is a delicate two-winged creature, bearing a straight stoutish appendage at the posterior end. It lives in this adult condition but a short time. The female never attains wings or leaves the scale after it is once formed.

Only in the active larval condition can the pest become spread. This is greatly facilitated by the habit of the larvæ of crawling on other insects or on the feet of birds, and being thus carried from tree to tree.

Remedies.—The sulphur-salt-lime wash applied in winter is a completely effective remedy on the Pacific coast. The ordinary practice in the Northwest is to spray in late winter after pruning. Care should be taken to spray every branch even to the very tip. If only a few of the insects escape, the whole tree may be again covered with them before the fruit is mature.

THE CODLING MOTH.

Fortunate, indeed, is the orchardist who does not know this insect from actual experience, yet there are portions of the Northwest where it is yet unknown.

The insect is the common "worm" of the apple and pear, and in the orchard may be easily detected (1) by the brownish castings which are thrust out of its burrow and then cling to the side of the fruit and (2) from the fact that many of the injured fruits fall prematurely to the ground.

Description and habits.—The larva is the young of a small purplish-brown moth, which measures a little more than half an inch from tip to tip. The first moths usually appear shortly after the apple trees are in bloom, but in the warmer regions they may appear before the blossoms open. The females deposit their eggs usually on the young apples, one or two in a place, and are capable of laying 40 or 50 eggs. In from six to eight days these eggs hatch into minute larvæ or "worms," which soon burrow into the young fruit, usually at the blossom end. Reaching the core when half grown, the larva eats out an irregular cavity, and sometimes may be found eating the seeds. The castings are thrown out through the hole by which the worm entered, or when the larva is full-grown and about to leave the apple, through a horizontal hole bored to the side. These castings are of a rusty reddish color and make the wormy apples quite easy to detect at this time. In about three weeks the larva reaches its full size and then leaves the fruit, either by crawling out of the hole and thence onto the tree or by dropping to the ground on a silken thread which it spins; many of the injured fruits drop to the ground, and not rarely this happens before

the larva has attained its full growth. In such case the worms crawl out of the fruit almost immediately.

The larvæ seek for protected places, such as crevices in the bark or cracks in the soil, and there spin thin cocoons, in which they soon change to brownish pupæ. In from twelve to twenty days the adult moths emerge, and a few days later eggs are laid from which a second brood of larvæ develops.

The larvæ of the second brood are peculiar in that they usually enter the fruit from the side, a favorite place being where apples touch. In most sections this second brood is quite distinct from the first in time of appearance, and the larvæ for the most part hibernate over winter. In the warmer valleys, however, there is a continuous succession of individuals from the first to the second broods, and even until the crop is harvested the insect may be found in every stage. This has usually been interpreted as indicating the existence of three or more broods.

The larvæ of the last brood in the year hibernate over winter in silken cocoons, and change into pupæ the following spring. The moths are rarely seen unless specially looked for or reared from pupæ. They fly mostly in the evening, and are not attracted to lights.

Remedies.—Spraying with the arsenicals is by far the most satisfactory means of combating this insect. The most important application is the first, which should be applied as soon as the petals fall from the blossoms, but not before. A prime object is to have the blossom end of the young pear or apple filled with the poison, as this is where the worm usually enters. In order to do this the fruit must be sprayed before the calyx cup at the blossom end closes, which is shortly after the fruit sets. Some growers spray the solution with considerable force, claiming that it yields better results by getting more poison in the calyx cup. A second spraying, about two or three weeks later, seems always profitable. The value of either of these sprayings may be completely destroyed by heavy rains following the application, in which case they will need to be repeated at once.

These two sprayings are all that are necessary in the greater part of the Coast region and in the inland uplands. In the warm inland valleys, however, more sprayings are required. Different growers apply these later sprayings at somewhat different dates. The third spraying is commonly given about July 10 to 15, the others at intervals of three weeks, the last in September.

In addition to spraying, some growers, especially in the warmer valleys, use the "banding system" as an additional means of protection. In this practice advantage is taken of the habit of the larvæ of seeking sheltered places in which to pupate. The simplest way is to fasten a strip of burlap around the trunk of the tree a foot or so above the ground. The burlap should reach around the trunk, and is conveniently fastened with a nail. If the trunk of the tree is clean and

free from loose bark most of the larvæ which escape the spraying will pupate beneath the burlap band and may there easily be killed. Where this system alone is depended on the bands are examined every ten or eleven days, because if a longer time elapses many of the moths will emerge. This practice alone is by no means as efficient as spraying alone. It would seem that, in any case, it would be desirable to use the bands to trap as many as possible of the last brood each year, thereby lessening the injury from them the following spring.

THE PEACH TWIG-BORER.

This insect injures the peach in two very different ways, namely, by burrowing into the fruit, making the so-called "wormy" peaches, and by boring into the twigs, which it frequently kills.

Description and habits.—The insect is usually noted in gathering the later varieties of peaches, the earlier ones being quite exempt, as a rule. The worm enters at the stem end, and usually bores into the seed, which it seems to prefer. In such cases the stone usually splits as the fruit ripens. At other times the worm burrows only through the flesh, making irregular tunnels. Whether the seed is attacked or not seems to depend on how far the stone has hardened when attacked. The larva is pinkish or dirty brown in color, about one-half an inch long, and very commonly changes into a pupa inside the split stone.

The adult is a small, dark-gray moth, marked on the fore-wings with a few dark spots and streaks. Both pairs of wings are bordered with a paler fringe. These adults issue in August and later, and lay their eggs in or near the crotches of the branches. When the eggs hatch, the young burrow into the bark in the crotch and feed on the soft, spongy bark until the succeeding spring. Their presence during the winter is disclosed by the fine brownish castings which are thrown out and become heaped up at the entrances to the burrows. Just as the leaves are developing in the spring they leave their winter quarters, and for a short time feed on the tender shoots. They bind the young leaves together loosely with silk threads, and later, when some of these leaves or the whole twig turns brown from the injuries, the work of the insect is very conspicuous.

At this time, however, the larva has usually left the leaves, and in some secluded place transforms into a pupa. From this the moth soon emerges and lays the eggs from which hatches the brood which attacks the fruit. According to Marlatt it is a third brood and not the second which enters the fruit.

Remedies.—Excellent results have been reached in Snake River Valley by spraying the trees in winter with kerosene emulsion, used preferably somewhat less diluted than for ordinary purposes. The castings at the mouths of the winter burrows readily absorb the oil, which penetrates into the holes and destroys the worms.

The sulphur-salt-lime wash has no appreciable effect on the insect.

THE WESTERN PULVINARIA OR COTTONY SCALE.

This insect is considered to be merely a variety of the Eastern cottony maple-scale, but it is very different in its food plants. While the Eastern insect attacks only the maple, the Western variety never is found on maples but has quite a long list of host plants, namely, currant, gooseberry, pear, mountain ash, lilac, alder, poplar, hawthorn, and willow. So far as known the life history is as follows:

During May and June the female lays the eggs in large numbers in a mass of white waxy fibers secreted from the posterior end of her body. As the eggs develop they expand the waxy mass and raise the insect's body to a considerable angle to the twig on which it is attached. If the waxy mass is crushed at this time blood-colored streaks appear, arising from the eggs and the bodies of the young larvæ which hatch from the eggs. These larvæ resemble lice and run about over the plant actively. About the time the last eggs are laid the female dies, but the tough leathery scale and the fluffy mass of fibers cling to the twig for a long time.

The young insects settle themselves on young twigs, insert their beaks, and begin to suck sap. They increase in size rapidly, after having covered themselves with tough waxy substance for protection, and reach their full size in August. About this time the male insects, which are narrower than the females, change into pupæ and soon after emerge as delicate two-winged creatures. After a few days' life, in which they pair with the female, they perish.

The females never become winged and seldom leave the branch on which they are born. After the flow of sap ceases they become dormant until the following spring.

As the female never acquires wings it seems at first sight difficult to account for the spread of the insect. Perhaps the most effective means of spreading the insect has been by infested nursery stock, as the insect is inconspicuous in winter. No doubt birds now and then carry the active young larvæ, which have crawled upon them, for considerable distances. Only thus can the fact be explained when the insect is found on a wild tree some distance from the nearest garden.

Remedies.—Spray during May and June with kerosene emulsion or whale-oil soap solutions, the aim being to destroy the young larvæ. Two sprayings are necessary, the first about the time the cottony mass is most conspicuous, the second a week or ten days later. On currant and gooseberry bushes the first spraying would be at the time the fruits are fully grown but before they have begun to ripen; the second spraying may be deferred until the crop is picked.

Winter spraying with the sulphur-salt-lime wash or with a strong solution of whale-oil soap, using $1\frac{1}{2}$ or 2 pounds of the soap to a gallon of water, would doubtless prove completely effective, but so far as we know the actual experiment has not been carried out.

THE GREEN APHIS OF THE APPLE.

Description and habits.—In winter a sharp inspection of the apple trees in the orchard will usually reveal the fact that some of them have their twigs literally covered with shiny black oval eggs, large enough to be seen easily with the naked eye. About the time the leaves develop in the spring these eggs hatch, and, curiously enough, all of them give rise to females. These females are peculiar in that after a few days they give birth to living young, and this without having been fertilized. They are, therefore, called agamic or virgin reproducing females. Similar broods follow each other quickly throughout the summer, and reproduce with wonderful rapidity. All of these summer broods, like the first, are composed of agamic females. Some of the broods are wholly or in part winged, and such spread the pest to other trees or orchards. As cold weather approaches there is produced a brood of perfect males and females. The latter lay the fertilized winter eggs by which the life of the insect is tided over to the following spring.

This insect varies in its abundance from year to year, and some places are much more troubled with it than others. In most orchards only a small portion of the trees are attacked, the insect seeming to pick out the weak or sickly ones especially. The damage done is not very great, but the attacked trees are unsightly on account of their distorted leaves and the dirty-black appearance caused by the excretions of the aphides.

Natural enemies.—On an aphis-infested tree are always found many other insects. The lady birds and lace-wing flies feed on the aphides and destroy great numbers of them. Ants are attracted and feed on the honey dew which the aphides excrete from two tube-like processes on their backs. It is a popular mistake that the ant destroys the green aphis. This is not the case. Besides the above, many other insects are found. Some are parasites of the aphides, but most of them are attracted by the honey dew.

Remedies.—It pays to search out in the winter the trees which are covered with eggs, and either to cut off the infested twigs or to spray the tree with sulphur-salt-lime, which kills the eggs. It does not pay to winter-spray a whole orchard for this insect, as is sometimes done.

Perhaps the most satisfactory method of controlling this insect is to spray with kerosene emulsion after the insects appear and before the leaves curl up from their attacks. It may be necessary to spray several times during the summer.

The same method is the best one for combating other species of aphis which attack trees.

THE WOOLLY APHIS OF THE APPLE.

Description and habits.—This insect exists in two forms, one of which attacks the roots, the other the trunk and the branches of apple trees. A great majority of the individuals are wingless, but winged ones also occur, especially in the later broods of the year. The species derives its name from a peculiar white fluffy substance which exudes from the insects' bodies, making them appear as though covered with cotton, and rendering them very conspicuous on the trees. They are especially liable to be abundant on the suckers from the bases of trees and in the forks of the branches. The cottony covering serves to some extent as a protection, so that this species is rather more difficult to kill than other aphides.

The root form of insect is the more injurious. By its attacks peculiar galls are formed on the roots, in the crevices of which the lice may be found. These galls not only interfere seriously with the functions of the roots, but also form centers of decay, and may cause the death of the tree.

The branch form weakens the tree by feeding on the sap, and not infrequently causes the bark to split in places as the result of its attacks; it never forms true galls like the root form. The entire life of the woolly aphis is spent on the apple tree, the winter eggs being laid in sheltered crevices.

It must be understood that the two forms differ mainly in their mode of life. The presence of either form will sooner or later give rise to the other, and badly infested trees are sure to be attacked both on the roots and on the branches.

This insect is most abundant in the Coast region. In Washington the writer has frequently searched for the root form without success. Professor Cordley reports it from the Willamette Valley.

Remedies.—This pest is far more likely to be introduced on nursery stock than in any other way. The roots of purchased apple trees should always be examined for the galls of this insect; if the galls are large or numerous, *reject the trees*. If they are small and few, they may be completely disinfected by dipping the roots in kerosene emulsion or in hot water (120°–140° F.) for a moment. If trees in the orchard are attacked by the root form, the soil should be removed as much as possible from them and the roots thoroughly treated with kerosene emulsion or with water heated nearly to the boiling point.

For the branch form, spray with kerosene emulsion, using rather stronger solutions than for other aphides.

The root galls caused by this insect should not be confounded with those of the crown-gall disease described elsewhere. Trees infested with the latter disease can not be disinfected by any known means. The safest rule is not to accept any trees with galls on the roots.

THE PEAR-LEAF BLISTER-MITE.

The presence of this pest is readily known by the bright red pimple-like spots that appear on the young leaves. Later these spots turn green and then brownish, forming cork-like thickenings on the under sides of the leaves. The cause of the spot is a minute four-legged mite, scarcely visible to the naked eye, and measuring but one one-hundred-and-fiftieth of an inch long. Its body is cylindrical in form and marked crosswise by numerous fine striae. As soon as the leaves burst from the buds in spring the mites burrow into them, forming the bright red galls, which are hollow and have minute openings on the under sides of the leaves. In these galls eggs are laid, which soon hatch into young mites. As fast as new leaves come out the mites migrate to them, forming new galls, and this process continues as long as leaves are developed. Before the leaves fall in autumn the mites crawl back to the twigs and pass the winter in cracks in the bark and similar places, but more particularly beneath the scales of the winter buds. At no stage of the mite's life is it able to move fast, but the pest becomes spread from tree to tree by crawling on insects, the feet of birds, and probably in other similar ways. The damage done is sometimes quite severe, as the function of the leaves is seriously impaired by their attacks. The affected leaves also fall prematurely.

Remedies.—Experiments with this pest have not been very satisfactory. Spraying in winter when the mites are under the bud scales with kerosene emulsion *diluted only three times* gave the best results, but this strength also injured the trees somewhat. In no instance were all the mites destroyed. Protracted periods of cold weather are fatal to the pest, and it was almost exterminated in the inland region during the winter of 1898-99.

BACTERIAL AND FUNGOUS DISEASES.

BLACKSPOT APPLE CANKER.

Description.—This disease has been demonstrated by Newton B. Pierce to be caused by a fungus which has recently been named by Peck, *Macrophoma curvispora*, and later by Cordley as *Malicorticis gloeosporium*. As the disease is unknown save in the Coast region of the Northwest, it is in all probability native, though it has not yet been found on wild trees. Apparently it attacks only the apple. Similar but far less serious diseases occur on both the pear and prune. The blackspot disease is confined to the bark, and derives its name from the characteristic dark brownish or nearly black spots which it causes. These spots appear only on smooth bark in which no cork has developed. Hence on old trees they are found only on the branches and twigs, but on young trees occur everywhere, being usually most

numerous on the trunks. The spots appear mostly in fall and winter, from November until January. They may easily be detected when no larger than a pin head. They increase quite rapidly in size and at the same time grow deeper, penetrating through the bark into the sap wood beneath, as evidenced by the brownish discoloration.

Nature of injury.—Almost from the first the spots are slightly sunken below the surrounding healthy bark, a fact evidently caused by the death and shrinking of the tissue. When the spots have attained their full dimensions, which occurs in February and later, the epidermis of the bark at the edge of the discolored spot commonly bursts. Still later in the season this deepens into a crack, which sharply separates the diseased from the healthy tissue. When once this crack has appeared the limit of the growth of the spot is reached, and beyond this limit it never spreads. The mature spots vary greatly in size and shape. Ordinarily they are oval, from 1 to 3 inches long and about half as wide; quite commonly two or more spots merge together, and not rarely girdle the trunk or branch. Sometimes the diseased areas are from 1 to 2 feet in length and completely girdle the attacked branch for the whole distance. On small twigs a similar girdling is very common.

When the spots are six months or more old numerous pustules as large as a pin head or larger burst through the dead epidermis. At first these pustules are whitish from the numerous spores borne on their surfaces, but as the spores fall off they become blackish. These spores are curved, colorless, about one-sixteen-hundredth of an inch long and one-fourth of that in width, and are borne singly on stalks as long as the spores. These spores are blown about in the air and by them the disease is spread. A spore will germinate readily in water, sending out a germ tube which later becomes branched into a mycelium. In nutrient substances this mycelium bears numerous secondary spores from the ends of short lateral branches. Under natural conditions these secondary spores seldom occur. The primary spores are able directly to give rise to new spots on healthy bark, the germ tubes apparently entering through a lenticel. This then completes the life history of the fungus as it occurs under natural conditions.

About the time the spores become mature the dead bark has usually separated from the wood beneath, being uplifted by the surrounding growing bark and wood, and sooner or later falls off, leaving the characteristic scars of the disease. When these scars are small and few, the new wood and bark may in time completely cover them. Unfortunately the spots are usually numerous enough to partially girdle the tree and so seriously weaken it as to make it almost worthless. Not rarely the trunks of young trees or the branches of older ones are completely girdled, which necessarily results in the death of all parts above such injury.

Remedies.—When the disease first appeared a common practice was to cut out the diseased spots while small and to paint over the resulting wounds. This was practicable only on the trunks of young trees, and where the spots were few was fairly satisfactory. When, however, a young tree trunk has dozens or even hundreds of such spots the remedy is nearly as bad as the disease, besides being extremely laborious. On the branches of old trees such a method is utterly impracticable.

From the foregoing account of the disease it is evident that the time when the tree needs protection most is from November 1 to February 1, and perhaps even later; at any rate, this is the period when most of the spots begin. Apparently such a fungicide as Bordeaux mixture should protect the trees during the period. The greatest difficulty arises from the fact that even Bordeaux mixture will not withstand the frequent fall and winter rains which prevail, unless applied several times. An ideal remedy would be a solution as effective as Bordeaux mixture for fungicidal purposes, and which would not wash off as readily. Experiments to discover such a wash if possible are now in progress.

APPLE SCAB.

Description.—Scab is without doubt the most destructive fungous disease in the Coast region. It commonly attacks both the leaves and the fruit, and sometimes occurs on young twigs as well. On the fruit the fungus forms circular spots of a dark smoky green or nearly black color, usually marked at the edge by a pale line where the skin of the apple is slightly raised. These spots begin to appear when the fruit is half grown, or even earlier. Single spots may reach the size of a dime, but ordinarily they are smaller. When close together they frequently unite and may thus occupy a considerable area. The effect of the fungous spot is to retard the growth of the apple tissue in its immediate vicinity, and when a number of spots are close together the apple becomes more or less distorted on that side. Where several spots merge together, irregular radiating cracks may appear.

On the leaves the fungus appears as dark olive green spots which are not sharply limited. They occur mostly on the upper side of the leaf, which may, indeed, be completely covered. The growth of the apple leaf where the spots occur is much hindered, so that the leaves are more or less curled or hummocky.

Microscopic examination of the fungus either from the leaves or fruit reveals that the part of the fungus seen consists of short upright stalks, each of which bears a single oval or spindle-form spore, which may or may not be divided by a cross partition. These spores float about in the air and thus spread the disease.

In comparatively rare cases where the twigs are attacked, the fungus lives over winter and in early spring again produces spores. Ordi-

narily, however, the disease commences in the spring from spores blown off the fallen leaves, or those which lodge in the crevices of winter buds.

Remedies.—In the light of present experience, three sprayings of Bordeaux mixture and two of cupram are necessary to insure a clean crop in the Coast region. The first spraying of Bordeaux should be just before the blossoms open, the second just after the petals fall, and the third ten or twelve days later. The two sprayings of cupram should follow the last spraying of Bordeaux at intervals of two weeks. Bordeaux should not be used for the fourth and fifth spraying, as it causes fruit to russet.

It is always good practice to prune the tops of trees, so as to induce an open growth. In such trees the apple scab causes conspicuously less damage than in dense ones.

PEAR SCAB.

This disease is so closely similar to the apple scab that no detailed account of it is necessary. Like the apple scab, it is much more injurious to some varieties than to others. In susceptible kinds such as the Winter Nelis, the twigs are very commonly attacked by the fungus, and in this as well as other varieties a large portion of the blossoms may be killed by the fungus on the flower stalk. This emphasizes the importance of the early sprayings, which are to be applied as recommended for the apple.

BROWN ROT OR FRUIT MOLD.

Description.—This is the only serious fungous disease of the plum, prune, cherry, and peach yet known in the orchards of the Northwest, where it has become introduced within the last few years. Usually the first symptom of this disease to attract attention is the numerous grayish-white pustules that appear on the attacked fruit when it is nearly ripe. The pustules consist of the reproductive bodies or spores of the fungus, and under the microscope are seen to be oval in shape and arranged in rows, like chains of beads. The disease is scattered by these spores being carried by the air currents, or in some cases by insects. Under favorable conditions the spores quickly germinate, sending out a germ tube that will penetrate a healthy fruit and soon cause it to rot. In the laboratory a single spore placed on a plum or cherry will develop so far in twenty-four hours as to produce new spores. From this it is easy to understand why the disease spreads so rapidly in orchards under favorable circumstances. In some cases a whole crop may be destroyed within a few days' time.

A curious feature of this fungus is that it causes the attacked fruit to become dry and hard, in which condition it may remain hanging on the tree for a long time. It is mainly on these fruits that the fungus passes the winter, and on such fruit the spores may be found in abun-

dance in the spring. While the spores will germinate almost immediately after they are formed, they can also withstand hardships, and will grow after they have been kept two years.

The pustules or blisters just described constitute only the reproductive parts of the fungus. In the interior of the fruit may be found innumerable filaments which make up the mycelium or vegetative part of the fungus.

Besides the fruit, the fungus also attacks the leaves, the flowers, and the twigs. When the flowers are affected they become brownish and rotten. In most cases it is through the stalk of the flower that the fungus enters the twig, where it sometimes causes serious damage, especially in the case of peach trees. The mycelium in the twigs lives from year to year, and the fungus may in this way have been introduced into the Northwest. The disease spreads much more rapidly in damp weather than in dry, so that the amount of damage it does is much more serious in some seasons than others.

Remedies.—As the fungus passes the winter mainly on the mummified or dried up fruits, these should always be gathered and burned. This treatment alone will often lessen the loss very materially.

It is also desirable to thin the fruit so that no clusters remain. Where a cluster of fruit is left, it frequently happens that all in the bunch are destroyed.

Spraying has not yielded perfectly satisfactory results with this disease on account of injury to the foliage. Two sprayings of Bordeaux—one just before the blossoms open, the other just after the petals fall—are usually recommended. The second spraying should be made with a Bordeaux containing a large excess of lime. Any later spraying is liable to result in defoliation of the trees.

PEAR BLIGHT.

This disease, which was exceedingly bad in 1899 and 1900 and hardly less so in 1901, may readily be recognized from the fact that the leaves and twigs of attacked branches turn black, giving the tree the appearance of having been scorched by fire, hence the popular designation, "fire blight." As has been fully demonstrated, the disease is caused by a species of bacteria or microscopic organism. As a result of the investigations made by Waite,^a the life history of this germ and the proper treatment for it are now well understood. The attack usually begins in the blossoms, less commonly in young twigs or young leaves. The disease rapidly works down the cambium layer between the bark and the wood, and the foliage quickly blackens. The leaves are quite often directly attacked by the disease, in which case only portions of them are blackened. It is uncommon for the disease to work down into the twig from the leaf.

^aM. B. Waite. The Cause and Prevention of Pear Blight. Yearbook U. S. Dept. of Agr., 1895, pp. 295-300.

Besides the pear, the same disease affects the quince and the apple. The apple is, however, quite resistant and rarely suffers injury.

The first appearance of the disease is usually after the flowering time. In 1901, owing probably to the cold weather, the disease did not become noticeable till the fruit was fairly well grown. An attacked branch is always killed and not rarely the whole tree succumbs. If left alone the disease usually continues to go down the branches during the greater part of the summer. Sooner or later, however, it ceases, and in the fall of the year one will find that in a majority of the blackened limbs, where the leaves cling a long time, there is a well-defined line between the dead blackened part and the healthy bark. On these limbs the disease has died out. On the other limbs, especially water sprouts, it will be found that there is no such line of demarcation, but the diseased portions fade insensibly into the healthy ones. On cutting into such a branch it is found to be moist, not dry as in the case of the dead limbs. It is in these comparatively few limbs that the blight germ lives over the winter. With the renewed growth in spring it frequently happens that a slimy sap exudes out of these limbs, which is swarming with the germs of the disease. Flies and bees are attracted to the juice, and then flying to the flowers are almost sure to leave in the honey pit some of the germs which have become attached to their beaks or feet. In the honey of the flower the germs rapidly multiply, and work thence downward into the twigs. As bees are very abundant on trees in flower it may readily be seen how the disease becomes spread.

Culture methods.—A peculiar fact about this disease is that it attacks first the most thrifty trees; slow-grown stunted trees are less liable to it. This fact has been taken advantage of in blight-infested regions by planting the pear and quince trees in very poor soil, thus insuring slow growth and a consequent partial immunity from the disease.

In richer lands the pear orchard should not be cultivated. In irrigated lands no more water should be given the pears than is absolutely necessary. It is well, too, not to prune the trees much, as this tends to force new growth, which is more favorable to the disease. Such methods are of value in the handling of a pear orchard.

Summer pruning.—In any case recourse must be had to cutting out the blight. This should be done as soon as it appears, care being taken to cut off each diseased sprig or branch well below the lowest trace of the blight. If the disease has run down a short lateral to a main branch, the latter must be cut off below the origin of the lateral. If the disease has reached the main trunk the tree is doomed. In this pruning it is quite easy to get the knife or the shears covered with the germs and thus spread the disease each time a cut is made. It is therefore well to dip the knife or shears now and then in a strong solution of carbolic acid, which will destroy any germs that may be on it.

As a result of considerable experience in summer pruning of the pear blight, we are able to say that the common fault is that the limbs are usually cut off too near the part which is diseased. It is best to make the cut at least a foot below the lowest blackening visible. In certain cases the disease may even have spread farther down than this without showing on the surface.

Fall or winter pruning.—This is, after all, the most important method of combating the disease. Examination of pear trees in the early winter will disclose the fact that most of the blighted limbs still have the dead leaves clinging to them, while the healthy limbs are bare. Careful search will also reveal the fact that in most of the limbs the disease has run its course and a sharp boundary line exists between the dead dry bark and the living green bark. It is of no importance whatever whether these dead blighted limbs be removed or not. In them the blight germ has perished and from them there can be no further spreading of the disease. In a very few cases, however, especially in young water shoots, it will be found that the bark is black and juicy, not dry, and that the disease-darkened bark fades gradually into the healthy bark. In these the blight germ is living, and it is in such branches that it survives the winter. If every branch containing living germs could be cut off in winter well below the lowest trace of the disease, pear blight could be exterminated. But a single limb of this kind may infect a whole orchard the following season. It is preferable to burn such branches; but if the pruning is done before February it is not necessary. It is very important, however, to take care that new inoculations of the disease are not made with the pruning knife or pruning shears. Merely cutting into diseased branches and then healthy ones frequently starts new infections; therefore, extreme care must be taken to keep the tool used free from the living germs.

To avoid the danger of losing the whole tree or larger branches the trunk should be kept free of water shoots and the fruiting spurs should be removed from the lower parts of the larger branches as suggested by Waite. If this is not done the blight may run down the short fruit spur and thus destroy a large branch. It is safe to say that 90 per cent of the infections which take place in the flowerless sprouts are probably caused by the punctures of insects which have just visited diseased parts. Experiments indicate that in no case can the blight enter an uninjured leaf or twig.

Virulence of the disease in the Northwest.—The above recommendations are based on the records of Eastern experience with the disease. It must be confessed the three years' experience with the disease in the inland fruit-growing districts of the Northwest have been discouraging. Intelligent use of the knife both in summer and fall will enable one to save his trees, more or less mutilated, however.

It would seem that the disease here is remarkably virulent. At least, the writer has been able to find no records of such wholesale destruction as it has caused in these inland districts. Unless the virulence of the disease should become lessened in the course of a few years, a phenomenon that would not be without parallel, the future of pear growing in these inland areas is not clear.

Some varieties, like Flemish Beauty, are notably more resistant than others, and a bright ray of hope exists in the possibility of transferring this resisting power to other varieties. This, however, will require many years of experimenting.

The Idaho pear is particularly susceptible to blight, and should not be planted in infested districts on that account.

CROWN GALL OR ROOT GALL.

This disease causes galls to appear on the roots of various trees and shrubs. On fruit trees it commonly forms spherical swellings of various sizes, occasionally as large as a walnut. These globular bodies have usually a peculiar warty surface. They should not be confused with the galls formed by woolly aphis, which, moreover, are smaller and usually oval or irregular. Besides in aphis galls some of the "wool" is usually to be found.

It frequently happens that when the roots are affected with this disease the secondary roots are abnormally abundant and often somewhat spongy in texture.

Particular attention is called to this disease because a good many nursery trees have been sold in the Northwest with the roots affected by it. A safer rule is to reject all trees diseased with the galls, even if the latter have been removed. We have found that they are sure to appear again.

No remedy is known, and, as the disease appears to be contagious, every effort should be made to prevent the sale of nursery stock affected by it.

Prof. J. W. Toumey has recently discovered in Arizona that the crown gall of the almond is caused by a slime mold which he names *Dendrophagus globosus*.

I have been unable to discover this or any similar organism in the galls on apple roots.

FARMERS' BULLETINS.

The following is a list of the Farmers' Bulletins available for distribution, showing the number, title, and size in pages of each. Copies will be sent to any address on application to Senators, Representatives, and Delegates in Congress, or to the Secretary of Agriculture, Washington, D. C. The missing numbers have been discontinued, being superseded by later bulletins.

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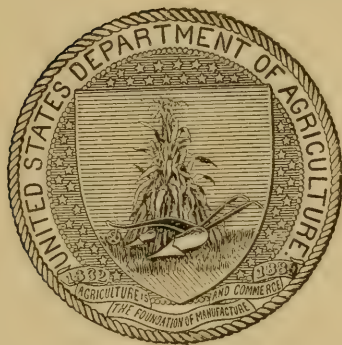
U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 155.

HOW INSECTS AFFECT HEALTH IN RURAL DISTRICTS.

BY

L. O. HOWARD,
Entomologist.



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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., May 10, 1902.

SIR: I transmit herewith copy of an article entitled "How Insects Affect Health in Rural Districts," and have the honor to recommend the publication of the same as a Farmers' Bulletin. The article was originally prepared by me for the Yearbook for 1901, in which it appears under a different title, but in view of the very general interest in the subject it seems desirable to republish the matter in the present form for distribution to farmers, to whom, it is believed, the bulletin will prove of special interest and value.

Very respectfully,

L. O. HOWARD,
Entomologist.

Hon. JAMES WILSON,
Secretary of Agriculture.

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HOW INSECTS AFFECT HEALTH IN RURAL DISTRICTS.

INTRODUCTION.

In very many parts of the country the farming population has to contend with at least two diseases which are preventable. These are malaria and typhoid fever. Both of these diseases are transferred or may be transferred by insects—malaria by certain mosquitoes and typhoid fever by the common house fly, or certain other flies.

CITY AND COUNTRY CONDITIONS COMPARED.

While it is true that both malaria and typhoid prevail in large cities, it is none the less true that they may with a certain degree of accuracy be termed country diseases, that is to say, rather specifically, diseases of the farm and the small village. Malaria, in fact, has been called by medical men a country disease. Swampy regions do not occur in cities, or, at all events, only in the suburbs, whereas they occur commonly in the country. Open streams with side pools of still water are found only in the country, and it is in such small, still pools, and in more or less permanent but small accumulations of water, that the malarial mosquito breeds. This mosquito, therefore, does not accommodate itself well to city conditions, but it is found almost everywhere in the country, except possibly in very dry localities and at certain high elevations. Even in dry regions it sometimes abounds, especially where there is a definite rainy season, or where the land is irrigated. Irrigating ditches are prolific breeding places for mosquitoes, including the malarial kind. Malaria in cities, as a rule, is found only with persons who have contracted it in the country or in the suburbs, although with some cities having marshy places on their borders a malarial belt may exist, the extent of which depends upon the direction and force of the prevailing summer breezes, especially the night breezes. For example, such a condition as this accounts for the prevalence of malaria in certain portions of the city of Washington before the reclamation of the Potomac Flats, which lie to the south of the city, the prevailing night breezes of the summer being southern.

SOURCES OF TYPHOID FEVER.

Cities well supplied with water from a reservoir, especially a filter reservoir, which possess a modern sewage system, and in which water-closets are universal, derive typhoid fever only from the follow-

ing sources: Contaminated country milk, the return of people in the autumn from the less sanitary country, and lack of care in the disposal of the discharges of persons who have contracted typhoid from either of the first two sources.

In the country, however, conditions are different. Each country house or each house in a small village has its own water supply, usually in the shape of a well; the cattle get water from the streams; there are no water-closets, and excreta are deposited in the open or in box privies; drainage from these box privies or from the open deposits containing virulent typhoid germs may enter the streams, be carried for some distance and be taken into the stomachs of cattle all along the course of the stream, or the germs may be carried by underground drainage directly into the wells from which drinking water is gained; or, exposed as these box privies or open deposits are, certain flies may alight upon the excrement and carry the germs directly to the food supply of the houses; or certain flies may breed in this excrement and fly, fairly reeking with disease-bearing filth, to the kitchens and tables of nearby houses. When we consider that active typhoid germs may be given out for some time by persons who have not developed typhoid fever sufficiently so that it may be recognized, and that they may also be given out for some time after patients have been apparently cured of the disease, it is perfectly obvious that in the country the lack of care with which excreta are deposited readily accounts for outbreaks of typhoid fever from any of the causes mentioned.

METHODS OF PROTECTION FROM TYPHOID AND MALARIA.

Of course it will be said that the entire water supply of a city may become contaminated at or immediately above its reservoir supply. This contamination is from country sources and might be obviated either in a general manner by the establishment of a reservoir filtering plant, or in a special manner by individual householders by the constant and thorough use of house filters. In cities possessing a common water supply and modern sanitary plumbing there is no excuse for the presence of typhoid in the household. Even the city water must be filtered, which can be done by the use of any one of the cheap filters now on the market; the milk which is drunk by children must be sterilized, and the excreta of persons returning to the city, after contracting typhoid fever in the country, must be disinfected with the utmost care. These three measures, systematically followed, will result in the abolition of typhoid fever within the city boundaries.

So much for cities. In the country the matter is somewhat more difficult, and immunity from malaria and typhoid depends largely upon the individual householder. Such immunity may be obtained, but only as a result of intelligent care.

Let us briefly consider what the farmer or the resident of a small village must do to bring about protection.

MALARIA.

The old idea that malaria is caused by breathing the miasma of swamps has been exploded. Malaria is contracted only through the bites of mosquitoes of the genus *Anopheles*. The cause of human malaria is the growth and development within the red blood cells of a very minute parasitic organism belonging to the lowest group of the animal kingdom—the group Protozoa, or one-celled animals, which includes those minute creatures known as *Amœbas* and others, and which live in the water or in damp sands or moss, or inside the bodies of other animals as parasites. This parasite reproduces in the body by subdividing, eventually bursting the red blood cells and entering the blood serum as a mass of spores. Broadly speaking, when the blood of a human being is sucked into the stomach of a mosquito of the genus *Anopheles* the malarial parasite undergoes a sexual development and gives birth to a large number of minute, spindle-shaped cells, known as blasts, which enter the salivary glands of the insect and are ejected with the poison into the system of the next person bitten by the mosquito. If this person happens to be nonmalarious the malaria has thus entered his system and malarial symptoms result.

So far as present knowledge goes, this is the only way in which people become malarious. In order to avoid this result it is necessary to avoid the bites of malarial mosquitoes, and it therefore becomes important to know the differences between the malarial and the more harmless mosquitoes, and the conditions under which the malarial forms breed.

Malaria-bearing mosquitoes.—There are very many mosquitoes which have not yet been proven to carry any disease. In fact, the majority of mosquitoes are supposed to be harmless except for the irritation caused by their punctures. The commonest of all forms belong to the genus *Culex*. These include the mosquitoes most commonly breeding in rain-water barrels and chance transient pools. Fig. 1 shows the difference between a harmless mosquito of the genus *Culex* and the malarious mosquito of the genus *Anopheles*. It will be noticed that *Culex* has clear wings, while *Anopheles* has wings which are more or less spotted. It will be noticed further that while the palpi (which are the projections either side of the beak) are very short in *Culex*, they are long—nearly as long as the beak—in *Anopheles*. Further, it has been observed that when *Culex* is resting upon a wall it appears more or less humpbacked, that is to say, the head and the beak are not in the same plane with the body and wings, but project at an angle toward the surface of the wall, the body and wings being parallel with the wall. With *Anopheles*, however, the head and beak are in prac-

tically the same plane with the body, and the body itself is usually placed at an angle with the wall, and especially when resting upon a



FIG. 1.—Adults of *Culex* and *Anopheles*: a, *Culex sollicitans*; b, *Anopheles punctipennis*—enlarged (author's illustration.)

horizontal wall, such as the ceiling of a room, the body of *Anopheles* is at a very great angle with the surface. We have in this country

three species of the malarial genus *Anopheles*, namely, *Anopheles maculipennis* (illustrated in fig. 2), *Anopheles punctipennis* (shown in fig. 1, *b*), and *Anopheles crucians* (shown in fig. 3). The two former are found nearly all over the country, but the last is a more Southern species, although it has been found as far north as the south shore of Long Island.

As to the early stages, the eggs of *Anopheles* may at once be distinguished from the eggs of *Culex* by figs. 4 and 5, those of *Culex* being laid in the raft-shaped mass on end and those of *Anopheles* being laid singly upon the surface of the water, always lying upon their



FIG. 2.—*Anopheles maculipennis*: Male at left; female at right—enlarged (author's illustration).

sides. The larvæ of *Culex*, commonly known as wigglers, are familiar to almost everyone, and are the common wigglers found in horse troughs and rain-water barrels, which wriggle around in the water, returning at frequent intervals to the surface to breathe, and when at the surface hanging with simply the tip of the tail extruding, the rest of the body being held below the surface at a great angle. What we have called the "tail" is simply the breathing tube, which, with the common *Culex* wigglers, is long and more or less pointed. With the malarial mosquitoes, however, the wiggler, or larva, is of somewhat different shape, as shown in figs. 6 and 7, and when resting at the surface, which

it does most of the time, it lies with its body parallel with the surface, and not hanging down, as does the *Culex wiggler*. The pupæ of both forms are shown in fig. 8, and need not be described.

Breeding places of malaria-bearing mosquitoes.—The breeding places of the harmless mosquitoes are more numerous and more varied than the breeding places of the malarial mosquitoes. *Anopheles*, however, are found under many divers conditions. They are found, as stated, in still side pools of small streams, in the swampy pools at the margins of larger ponds, in stagnant water in ditches, in the beds of old canals,



FIG. 3.—*Anopheles crucians*—enlarged (author's illustration).

in the still water at the sides of springs, and occasionally, though rarely, in old horse troughs. They are perhaps more frequently found in such situations as described when a certain amount of green scum has accumulated, and it is upon the spores of the water plants constituting this green scum, as well as upon other very small objects floating on the surface of the water, that they principally feed.

Measures to be taken to prevent malaria.—To prevent malarial mosquitoes from breeding in a given vicinity, one should be prepared to recognize their larvæ when they are seen, and to distinguish them from other mosquito larvæ; then a most thorough search for all possible

breeding places should be made within a radius of a mile. This distance is mentioned, since it seems rather definitely proven that the *Anopheles* mosquitoes do not fly for great distances. After the breeding places are found they should be drained or filled in with earth, or they should be rendered uninhabitable to the *Anopheles* larvæ by covering the surface of the water with a thin film of kerosene oil, or by introducing certain fish which feed upon the larvæ, such as top minnows, sticklebacks, young sunfish, or goldfish.

Pending the result of such exterminating measures, all houses in malarious localities should be carefully screened to prevent the entrance



FIG. 4.—Eggs of *Anopheles*—enlarged (author's illustration).

of mosquitoes. After screening, thorough search should be made in the house for mosquitoes which have already gained entrance. Such as are found roosting upon the walls should be captured by placing an inverted vial over them, or they may be stupefied by burning a small amount of pyrethrum powder upon a tin-dish cover. Persons wishing to avoid malaria should not sit out of doors exposed to the bites of mosquitoes at night. Persons having malaria should be carefully screened at night to prevent them from being bitten by mosquitoes, which, becoming thus infected, would become potential carriers of the disease. Such patients, systematically treated with quinine, the dose being always given at the beginning of the chill, will soon be rid

of the disease. The time of the dose is important, and the reasons for the time have been abundantly proven by the study of the life of the parasite in the blood cells.

All of this advice is given only after abundant demonstration of the efficacy of the methods. These measures have been followed with success in the most malarious localities in the world, and with this knowledge there is no good reason why an individual should contract malaria in his own home, no matter how much malaria exists around him.

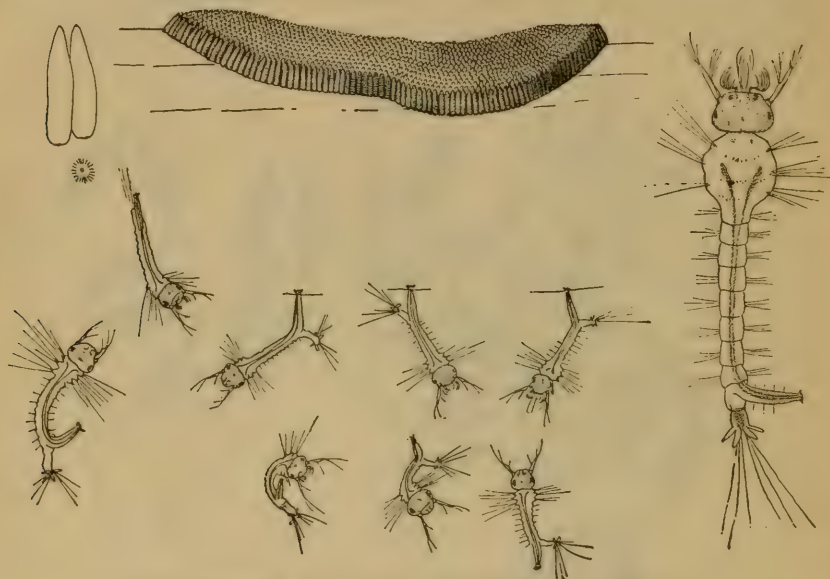


FIG. 5.—Eggs and larvæ of *Culex*—enlarged (author's illustration).

Of course, however, there may be occasions where it is almost impossible to avoid contracting the disease. For example, last October the writer was waiting for a night train one evening in a small Western town where there were irrigating ditches near the station. In these ditches malarial mosquitoes were breeding profusely, and the insects abounded in the station waiting room and on the platform. Nothing but a gauze covering would have kept them away, and several bites were inflicted on the hands and neck. Fortunately, none of the individuals could have bitten a malarial patient, as the disease was not transmitted.

TYPHOID FEVER.

It is not the writer's intention to go further into the causation of this disease than he has already done in his introductory remarks. He wishes, however, to point out as forcibly as possible the danger of its spread by insects and the methods of avoiding this danger.

House flies and breeding places.—The principal insect agent in this spread is the common house fly (fig. 9), and this insect is especially

abundant in country houses in the vicinity of stables in which horses are kept. The reason for this is that the preferred food of the larvæ of house flies is horse manure. House flies breed in incredible numbers in a manure pile largely derived from horses. Twelve hundred house flies, and perhaps more, will issue from a pound of horse manure. Ten days completes a generation of house flies in the summer. The number of eggs laid by each female fly averages 120. Thus, under favorable conditions, the offspring of a single over-wintering house fly may in the course of a summer reach a figure almost beyond belief.

With an uncared-for pile of horse manure in the vicinity of a house, therefore, flies are sure to swarm. Their number practically will be limited only by breeding opportunities. They are attracted to, and will lay their eggs in, human excrement. Under favorable conditions they will breed, to some extent, in this excrement. They swarm in kitchens and dining rooms where food supplies are exposed. They are found commonly in box privies, which sometimes are not distant from the kitchens and dining rooms. Therefore, with an abundance of flies, with a box privy near by, or with excremental deposits in the neighborhood, and with a perhaps unsuspected or not yet fully developed case of typhoid in the immediate neighborhood, there is no reason why, through the agency of contaminated flies alighting upon food supplies, the disease should not be spread to healthy individuals. That it is so spread is not to be questioned. That under the unusual conditions of the army concentration camps in the summer of 1898 it was so spread to a shocking extent has been demonstrated by the army typhoid fever commission. And the remedy is plain. It consists of two courses of procedure: (1) Proper care of excreta; (2) the destruction of flies.

Measures to be taken to prevent typhoid fever.—On many farms where intelligent people live the old-fashioned box privy has been done away with, and there has been substituted for it some form of earth closet. Where a good earth closet is in operation, and the inhabitants of a farm appreciate the importance of using no other, and where in case

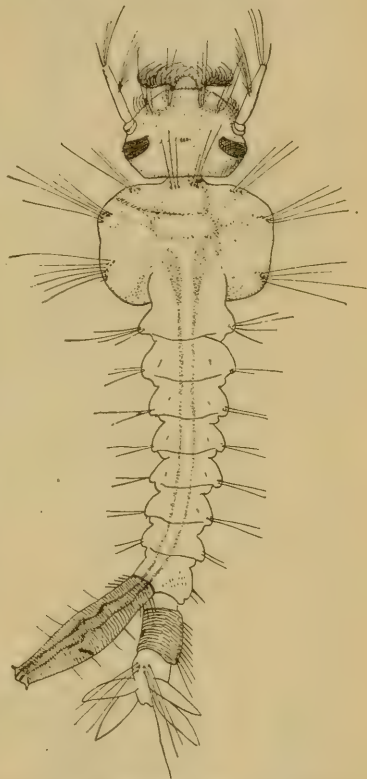


FIG. 6.—Full-grown larva of *Culex*—enlarged (author's illustration).

of illness the excreta of patients are promptly disinfected, flies breeding in the neighborhood will have practically no opportunity to become contaminated with typhoid germs, except in the unlikely event (which future investigation may possibly show) that other animals than man are subject to this disease. The proper maintenance of an earth closet

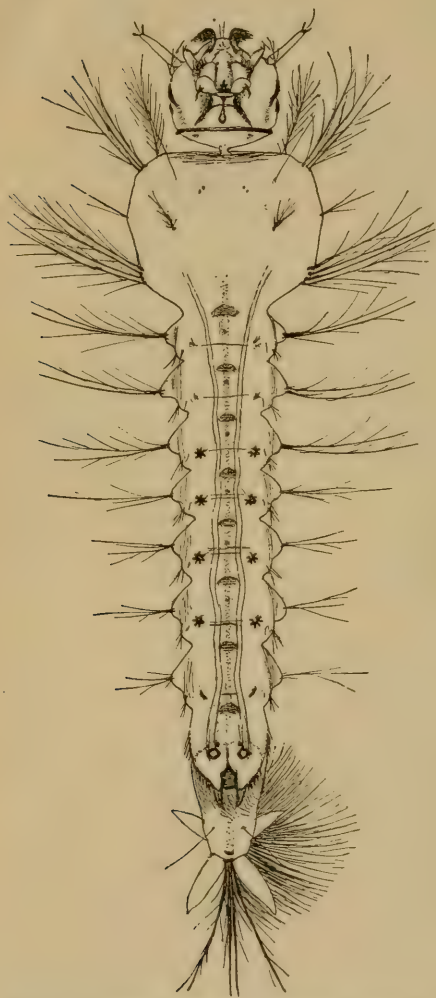


FIG. 7.—Full-grown larva of *Anopheles*—greatly enlarged (author's illustration).

will add somewhat to the work of a farm, but this extra work will pay in the long run. While it is true that a box inclosure, if its contents are covered with lime every three or four days, will answer the purpose, a much better plan would be to use a large metal vessel, the surface of the contents being covered with earth after each operation, and which may be removed, emptied, and replaced daily. Care should, of course, be taken to empty the contents of the vessel in a pit constructed in some well-chosen spot, from which the drainage would not be dangerous.

With regard to the abolition of flies, the best measures will again naturally involve some trouble and expense. In a thickly settled country it will become necessary for some such measure to be generally adopted in order to be perfectly effective, but in an isolated farmhouse the number of house flies may be greatly reduced by indi-

vidual work. All horse manure accumulating in stables or barns should be collected, if not daily, at least once a week, and should be placed in either a pit or vault or in a screened inclosure like a closet at the side or end of the stable. This closet should have an outside door from which horse manure can be shoveled when it is needed for manuring

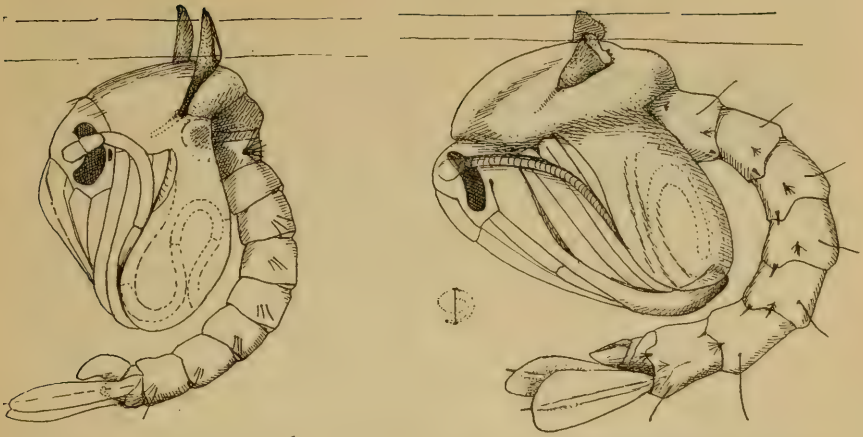


FIG. 8.—Pupa of *Culex* (at left) and *Anopheles* (at right)—greatly enlarged (author's illustration).



FIG. 9.—Common house fly (*Musca domestica*): Puparium at left; adult next; larva and enlarged parts at right—enlarged (author's illustration).

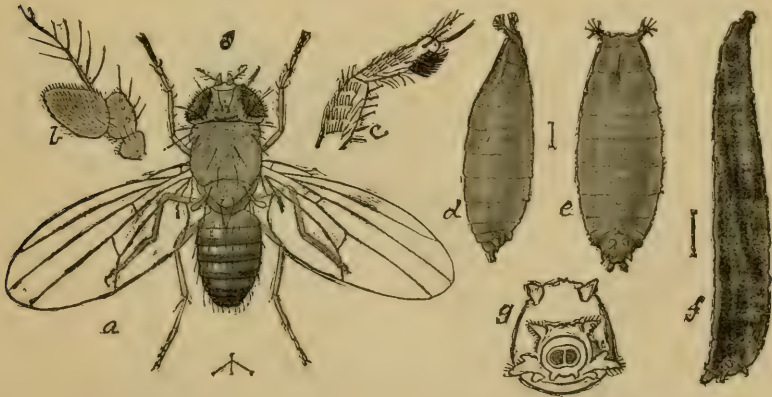


FIG. 10.—*Drosophila ampelophila*: *a*, adult; *b*, antenna of same; *c*, base of tibia and first tarsal joint of same; *d*, puparium, side view; *e*, puparium from above; *f*, full-grown larva; *g*, anal spiracles of same—enlarged (author's illustration).

purposes. Each day's or each week's accumulations, after they are shoveled into the closet or pit, should be sprinkled over the surface with chloride of lime, and a barrel of this substance can conveniently be kept in the closet. If this plan be adopted (and these recommendations are the result of practical experience), house flies will have almost no chance to breed, and their numbers will be so greatly reduced that they will hardly be noticeable. Many experiments

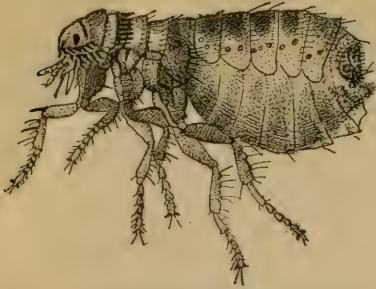


FIG. 11.—Cat and dog flea—enlarged (original).

have been made in the treatment of manure piles in order to kill the



FIG. 12.—Cattle tick—enlarged (redrawn from Salmon and Stiles).

maggots of the house fly, and the chloride-of-lime treatment has been found to be the cheapest and most efficacious.

It has been stated above that the closet for the reception of manure should be made tight to prevent the entrance or exit of flies. A window fitted with a wire screen is not desirable, since the corroding chloride fumes will ruin a wire screen in a few days.

Fruit flies.—While extended investigations have shown that the common house fly is the fly most to be feared in guarding against typhoid, on account of the fact



FIG. 13.—Tsetse fly—enlarged (original).

that over 99 per cent of the flies found in kitchens and dining rooms and attracted to food supplies are house flies, there are a few others which are attracted to and which may breed in human excrement that also have to be guarded against, and as these do not breed in horse manure the treatment just described will not be effective against them. The care of human excrement, however, will prevent the carriage of typhoid germs even by these species. The little fruit flies of the genus *Drosophila* (fig. 10), which breed in overripe or decaying fruit, are the principal species in this category. Therefore, fruit store-houses or fruit receptacles should be screened, and overripe fruit should not be allowed to remain in dining rooms or kitchens for any length of time.

OTHER DISEASES CARRIED BY INSECTS.

While in malaria and typhoid we have the two principal diseases common to the United States which may be conveyed by insects, the

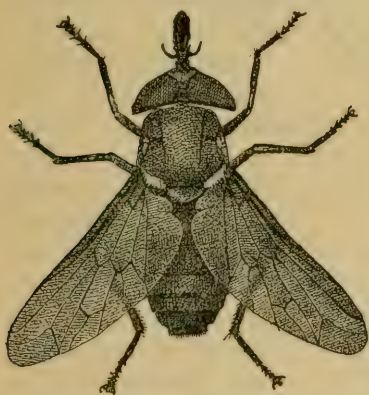


FIG. 14.—Black gadfly—enlarged (original).



FIG. 15.—Bedbug—enlarged (after Marlatt).

agency of these little creatures in the transfer of disease germs is much more widespread in warm countries, and it is by no means confined to human beings. In Egypt and in the Fiji Islands there is a destructive eye disease of human beings the germs of which are carried by the common house fly. In our Southern States an eye disease known as pink-eye is carried by certain very minute flies of the genus *Hippelates*. In certain tropical countries a disease known as filariasis, which somewhat resembles certain forms of leprosy, is transferred among human beings by certain mosquitoes. There is good reason to suppose that the germs of the bubonic plague may be transferred from sick people to healthy people by the bites of fleas (fig. 11). The so-called Texas fever of cattle is unquestionably transferred by the common cattle tick (fig. 12), and this was the earliest of the clearly demonstrated cases of the transfer of disease by insects. In

Africa a similar disease of cattle is transferred by the bite of the famous biting fly known as the tsetse fly (fig. 13). The germs of the disease of cattle known as anthrax are carried by gadflies, or horse flies, and when these flies subsequently bite human beings malignant pustules may result (see fig. 14 for one of these gadflies); and other discoveries of this nature are constantly being made. Even the common bedbug (fig. 15) is strongly suspected in this connection.

YELLOW FEVER.

One of the most important of these disease-transfer relations of insects which has been demonstrated is the recently proved carriage of yellow fever by certain mosquitoes. The cause of yellow fever has



FIG. 16.—*Stegomyia fasciata*—enlarged (author's illustration).

always been a mystery, and indeed it is a mystery to-day in a measure, since although undoubtedly a disease of parasitic origin, the parasitic organism itself has not yet been discovered. During the summer and autumn of 1900 and spring and summer of 1901 the work of a commission of surgeons of the United States Army has demonstrated in Cuba beyond the slightest possible doubt that yellow fever is not conveyed

by infected clothing of yellow-fever patients or by contact with such patients or by proximity to them, but that it is conveyed by the bite of a certain species of mosquito known as *Stegomyia fasciata* (fig. 16), which abounds in regions where yellow fever is possible. The bite of this mosquito, however, does not convey yellow fever to a healthy person until twelve days have elapsed from the time when the same mosquito has bitten a person suffering with the disease. It follows from this fact that by keeping yellow-fever patients screened from the possibilities of mosquito bites we can prevent the yellow-fever mosquito from becoming infected. It follows further that by preventing healthy people from being bitten by mosquitoes we can keep them free from the disease even where infected mosquitoes exist. And it follows still

further that by the adoption of remedial measures looking toward the destruction in all stages of the yellow-fever mosquito we may reduce to a minimum the possibilities of the transfer of the disease. After demonstrating the fact, the medical officers of the Army in Cuba have put these measures into effect, and the results have been most gratifying. The health of Havana has constantly improved, and at the date of present writing the published statement has just been made that during the month of October, 1901, there was not a single case of yellow fever in Havana, while October is usually the severest month for that disease, and in fact during the past ten years the average number of deaths in the city during that month from yellow fever has been 66.27. This discovery, and this practical demonstration of its truth, it seems must soon change all methods of quarantine in the United States; and it seems certain that in the future the Gulf cities will no longer dread the disease or remain subject to the great vital and economic loss to which they have been subject from occasional yellow-fever outbreaks during past generations.

FARMERS' BULLETINS.

The following is a list of the Farmers' Bulletins available for distribution, showing the number and title of each. Copies will be sent to any address on application to any Senator, Representative, or Delegate in Congress, or to the Secretary of Agriculture, Washington, D. C.

No. 22. The Feeding of Farm Animals. No. 24. Hog Cholera and Swine Plague. No. 25. Peanuts Culture and Uses. No. 27. Flax for Seed and Fiber. No. 28. Weeds: And How to Kill Them. No. 29. Souring and Other Changes in Milk. No. 30. Grape Diseases on the Pacific Coast. No. 32. Silos and Silage. No. 33. Peach Growing for Market. No. 34. Meats: Composition and Cooking. No. 35. Potato Culture. No. 36. Cotton Seed and Its Products. No. 37. Kafir Corn: Culture and Uses. No. 38. Spraying for Fruit Diseases. No. 39. Onion Culture. No. 41. Fowls: Care and Feeding. No. 43. Sewage Disposal on the Farm. No. 44. Commercial Fertilizers. No. 46. Irrigation in Humid Climates. No. 47. Insects Affecting the Cotton Plant. No. 48. The Manuring of Cotton. No. 49. Sheep Feeding. No. 50. Sorghum as a Forage Crop. No. 51. Standard Varieties of Chickens. No. 52. The Sugar Beet. No. 54. Some Common Birds. No. 55. The Dairy Herd. No. 56. Experiment Station Work—I. No. 57. Butter Making on the Farm. No. 58. 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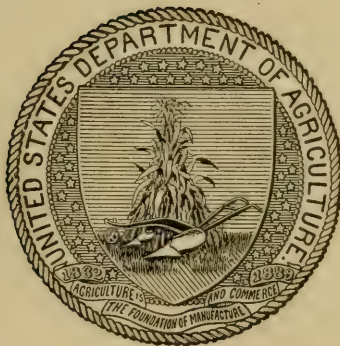
HOW INSECTS AFFECT HEALTH IN RURAL DISTRICTS.

BY

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(REVISED EDITION.)



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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., April 7, 1908.

SIR: I have the honor to transmit herewith a revision of Farmers' Bulletin No. 155, entitled "How Insects Affect Health in Rural Districts," and recommend its republication in the present form. The article was originally prepared by me for the Yearbook for 1901, in which it appears under a different title, but in view of the very general interest in the subject it has seemed desirable to republish the matter for wide distribution to farmers, to whom the information contained in the article is especially pertinent.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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HOW INSECTS AFFECT HEALTH IN RURAL DISTRICTS.

INTRODUCTION.

In very many parts of the country the farming population has to contend with at least two diseases which are preventable. These are malaria and typhoid fever. Both of these diseases are transferred or may be transferred by insects—malaria by certain mosquitoes and typhoid fever by the common house fly, or certain other flies.

CITY AND COUNTRY CONDITIONS COMPARED.

While it is true that both malaria and typhoid prevail in large cities, it is none the less true that they may with a certain degree of accuracy be termed country diseases, that is to say, rather specifically, diseases of the farm and the small village. Malaria, in fact, has been called by medical men a country disease. Swampy regions do not occur in cities, or, at all events, only in the suburbs, whereas they occur commonly in the country. Open streams with side pools of still water are found only in the country, and it is in such small, still pools, and in more or less permanent but small accumulations of water, that the malarial mosquito breeds. This mosquito, therefore, does not accommodate itself well to city conditions, but it is found almost everywhere in the country, except possibly in very dry localities and at certain high elevations. Even in dry regions it sometimes abounds, especially where there is a definite rainy season, or where the land is irrigated. Irrigating ditches are prolific breeding places for mosquitoes, including the malarial kind. Malaria in cities, as a rule, is found only with persons who have contracted it in the country or in the suburbs, although with some cities having marshy places on their borders a malarial belt may exist, the extent of which depends upon the direction and force of the prevailing summer breezes, especially the night breezes. For example, such a condition as this accounts for the prevalence of malaria in certain portions of the city of Washington before the reclamation of the Potomac Flats, which lie to the south of the city, the prevailing night breezes of the summer being southern.

SOURCES OF TYPHOID FEVER.

Cities well supplied with water from a reservoir, especially a filter reservoir, which possess a modern sewage system, and in which water-closets are universal, derive typhoid fever only from the following sources: Country milk contaminated through vessels washed in water infected with typhoid germs, the return of people in the autumn from the less sanitary country, and lack of care in the disposal of the discharges of persons who have contracted typhoid from either of the first two sources.

In the country, however, conditions are different. Each country house or each house in a small village has its own water supply, usually in the shape of a well; there are few water-closets, and excreta are deposited in the open or in box privies; drainage from these box privies or from the open deposits containing virulent typhoid germs may enter the streams, or the germs may be carried by underground drainage directly into the wells from which drinking water is gained; or, exposed as these box privies or open deposits usually are, certain flies may alight upon the excrement and carry the germs directly to the food supply of the houses; or certain flies may breed in this excrement and fly, fairly reeking with disease-bearing filth, to the kitchens and tables of nearby houses. When we consider that active typhoid germs may be given out for some time by persons who have not developed typhoid fever sufficiently so that it may be recognized, and that they may also be given out for some time after patients have been apparently cured of the disease, it is perfectly obvious that in the country the lack of care with which excreta are deposited readily accounts for outbreaks of typhoid fever from any of the causes mentioned.

METHODS OF PROTECTION FROM TYPHOID AND MALARIA.

Of course it will be said that the entire water supply of a city may become contaminated at or immediately above its reservoir supply. This contamination is from country sources and might be obviated either in a general manner by the establishment of a reservoir filtering plant, or in a special manner by individual householders by the constant and thorough use of house filters. In cities possessing a common water supply and modern sanitary plumbing there is no excuse for the presence of typhoid in the household. Even the city water must be filtered, which can be done by the use of any one of the cheap filters now on the market; the milk which is drunk by children must be sterilized, and the excreta of persons returning to the city, after contracting typhoid fever in the country, must be disinfected with the utmost care. These three measures, systematically followed, will result in the abolition of typhoid fever within the city boundaries.

So much for cities. In the country the matter is somewhat more difficult, and immunity from malaria and typhoid depends largely upon the individual householder. Such immunity may be obtained, but only as a result of intelligent care.

Let us briefly consider what the farmer or the resident of a small village must do to bring about protection.

MALARIA.

The old idea that malaria is caused by breathing the miasma of swamps has been exploded. Malaria is contracted only through the bites of mosquitoes of the genus *Anopheles*. The cause of human malaria is the growth and development within the red blood cells of a very minute parasitic organism belonging to the lowest group of the animal kingdom—the group Protozoa, or one-celled animals, which includes those minute creatures known as *Amœbas* and others, and which live in the water or in damp sands or moss, or inside the bodies of other animals as parasites. This parasite reproduces in the body by subdividing, eventually bursting the red blood cells and entering the blood serum as a mass of spores. Broadly speaking, when the blood of a human being is sucked into the stomach of a mosquito of the genus *Anopheles* the malarial parasite undergoes a sexual development and gives birth to a large number of minute, spindle-shaped cells, known as blasts, which enter the salivary glands of the insect and are ejected with the poison into the system of the next person bitten by the mosquito. If this person happens to be nonmalarious the malaria has thus entered his system and malarial symptoms result.

So far as present knowledge goes this is the only way in which people become malarious. In order to avoid this result it is necessary to avoid the bites of malarial mosquitoes, and it therefore becomes important to know the differences between the malarial and the more harmless mosquitoes, and the conditions under which the malarial forms breed.

Malaria-bearing mosquitoes.—There are very many mosquitoes which have not yet been proven to carry any disease. In fact, the majority of mosquitoes are supposed to be harmless except for the irritation caused by their punctures. The commonest of all forms belong to the genus *Culex*. These include the mosquitoes most commonly breeding in rain-water barrels and chance transient pools. Fig. 1 shows the difference between a harmless mosquito of the genus *Culex* and the malarious mosquito of the genus *Anopheles*. It will be noticed that *Culex* has clear wings, while *Anopheles* has wings which are more or less spotted. It will be noticed further that while the palpi (which are the projections either side of the beak) are very short in *Culex*, they are long—nearly as long as the beak—in *Anopheles*. Further,



a



b

FIG. 1.—Adults of *Culex* and *Anopheles*: a, *Culex sollicitans*; b, *Anopheles punctipennis*. Enlarged (author's illustration).

it has been observed that when *Culex* is resting upon a wall it appears more or less humpbacked, that is to say, the head and the beak are not in the same plane with the body and wings, but project at an angle toward the surface of the wall, the body and wings being parallel with the wall. With *Anopheles*, however, the head and beak are in practically the same plane with the body, and the body itself is usually placed at an angle with the wall, and especially when resting upon a horizontal wall, such as the ceiling of a room, the body of *Anopheles* is at a very great angle with the surface. We have in this country three species of the malarial genus *Anopheles*, namely, *Anopheles maculipennis* (illustrated in fig. 2), *Anopheles punctipennis* (shown in fig. 1, b), and *Ano-*

pheles crucians (shown in fig. 3). The former two are found nearly all over the country, but the last is a more Southern species, although it has been found as far north as the south shore of Long Island.

As to the early stages, the eggs of *Anopheles* may be at once distinguished from the eggs of *Culex* by figs. 4 and 5, those of *Culex* being laid in the raft-shaped mass on end and those of *Anopheles* being laid singly upon the surface of the water, always lying upon their sides. The larvæ of *Culex*, commonly known as wigglers, are



FIG. 2.—*Anopheles maculipennis*: Male at left; female at right. Enlarged (author's illustration).

familiar to almost everyone, and are the common wigglers found in horse troughs and rain-water barrels, which wriggle around in the water, returning at frequent intervals to the surface to breathe, and when at the surface hanging with simply the tip of the tail extruding, the rest of the body being held below the surface at a great angle. What we have called the "tail" is simply the breathing tube, which, with the common *Culex* wigglers, is long and more or less pointed. With the malarial mosquitoes, however, the wiggler, or larva, is of somewhat different shape, as shown in figs. 6 and 7, and when resting

at the surface, which it does most of the time, it lies with its body parallel with the surface, and not hanging down, as does the *Culex* wiggler. The pupæ of both forms are shown in fig. 8, and need not be described.

Breeding places of malaria-bearing mosquitoes.—The breeding places of the harmless mosquitoes are more numerous and more varied than the breeding places of the malarial mosquitoes. *Anopheles*, however, are found under many diverse conditions. They are found, as stated, in still side pools of small streams, in the swampy pools at the margins

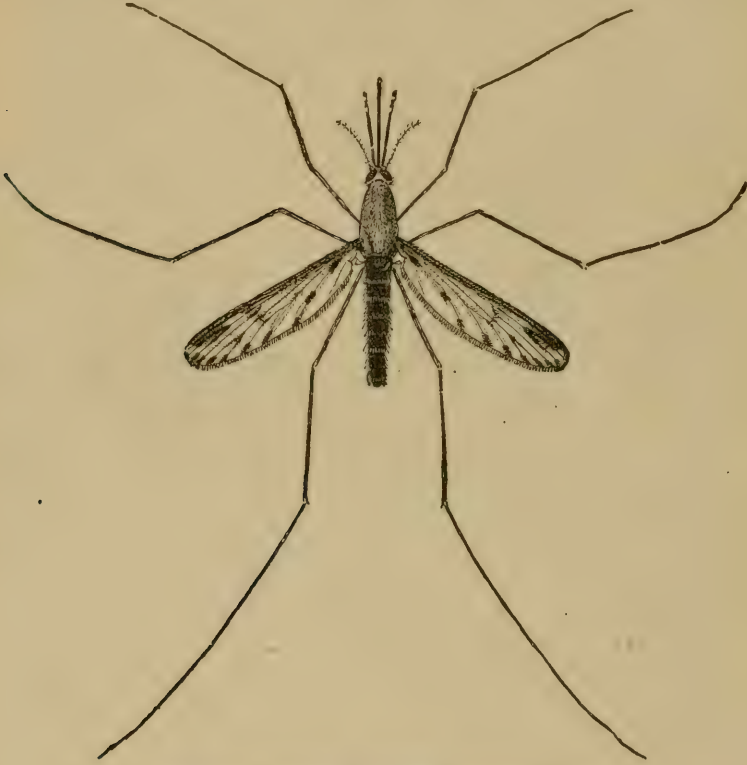


FIG. 3.—*Anopheles crucians*. Enlarged (author's illustration).

of larger ponds, in stagnant water in ditches, in the beds of old canals, in the still water at the sides of springs, and occasionally, though rarely, in old horse troughs. They are perhaps more frequently found in such situations as described when a certain amount of green scum has accumulated, and it is upon the spores of the water plants constituting this green scum, as well as upon other very small objects floating on the surface of the water, that they principally feed.

Measures to be taken to prevent malaria.—To prevent malarial mosquitoes from breeding in a given vicinity, one should be prepared to

recognize their larvæ when they are seen, and to distinguish them from other mosquito larvæ; then a most thorough search for all possible breeding places should be made within a radius of a mile. This distance is mentioned, since it seems rather definitely proven that the *Anopheles* mosquitoes do not fly for great distances. After the breeding places are found they should be drained or filled in with earth, or they should be rendered uninhabitable to the *Anopheles* larvæ by covering the surface of the water with a thin film of kerosene oil, or by introducing certain fish which feed upon the larvæ, such as top minnows, sticklebacks, young sunfish, or goldfish.



FIG. 4.—Eggs of *Anopheles*. Enlarged (author's illustration).

Pending the result of such exterminating measures, all houses in malarious localities should be carefully screened to prevent the entrance of mosquitoes. After screening, thorough search should be made in the house for mosquitoes which have already gained entrance. Such as are found roosting upon the walls should be captured by placing an inverted vial over them, or they may be stupefied by burning a small amount of pyrethrum powder upon a tin dish cover. Persons wishing to avoid malaria should not sit out of doors exposed to

the bites of mosquitoes at night. Persons having malaria should be carefully screened at night to prevent them from being bitten by mosquitoes, which, becoming thus infected, would become potential carriers of the disease. Such patients, systematically treated with quinine, the dose being always given at the beginning of the chill, will soon be rid of the disease. The time of the dose is important, and the reasons for the time have been abundantly proven by the study of the life of the parasite in the blood cells.

All of this advice is given only after abundant demonstration of the efficacy of the methods. These measures have been followed with success in the most malarious localities in the world, and with this knowledge there is no good reason why an individual should contract

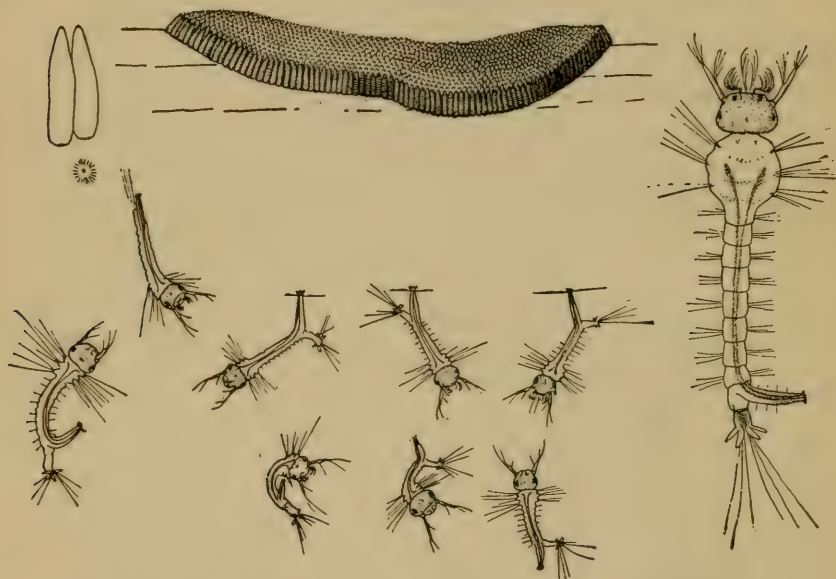


FIG. 5.—Eggs and larvæ of *Culex*. Enlarged (author's illustration).

malaria in his own home, no matter how much malaria exists around him.

Of course, however, there may be occasions where it is almost impossible to avoid contracting the disease. For example, the writer was once waiting for a night train one evening in a small Western town where there were irrigating ditches near the station. In these ditches malarial mosquitoes were breeding profusely, and the insects abounded in the station waiting room and on the platform. Nothing but a gauze covering would have kept them away, and several bites were inflicted on the hands and neck. Fortunately, none of the individuals could have bitten a malarial patient, as the disease was not transmitted.

TYPHOID FEVER.

It is not the writer's intention to go further into the causation of this disease than he has already done in his introductory remarks. He wishes, however, to point out as forcibly as possible the danger of its spread by insects and the methods of avoiding this danger.

House flies and breeding places.—The principal insect agent in this spread is the common house fly (fig. 9), and this insect is especially abundant in country houses in the vicinity of stables in which horses are kept. The reason for this is that the preferred food of the larvæ of house flies is horse manure. House flies breed in incredible numbers in a manure pile largely derived from horses. Twelve hundred house flies, and perhaps more, will issue from a pound of horse manure. Ten days completes a generation of house flies in the summer. The number of eggs laid by each female fly averages 120. Thus, under favorable conditions, the offspring of a single over-wintering house fly may in the course of a summer reach a figure almost beyond belief. With an uncared-for pile of horse manure in the vicinity of a house, therefore, flies are sure to swarm. Their number practically will be limited only by breeding opportunities. They are attracted to, and will lay their eggs in, human excrement. Under favorable conditions they will breed, to some extent, in this excrement. They swarm in kitchens and dining rooms where food supplies are exposed. They are found commonly in box privies, which sometimes are not distant from the kitchens and dining rooms. Therefore, with an abundance of flies, with a box privy near by, or with excremental deposits in the neighborhood, and with a perhaps unsuspected or not yet fully developed case of typhoid in the immediate neighborhood, there is no reason why, through the agency of contaminated flies alighting upon food supplies the disease should not be spread to healthy individuals. That it is so spread is not to be questioned. That under the unusual conditions of the army concentration camps

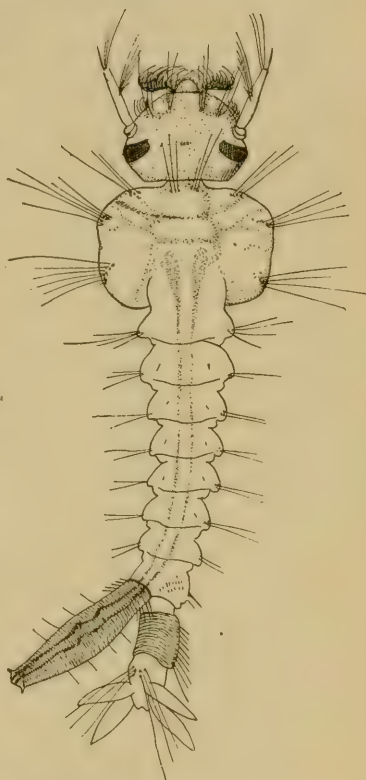


FIG. 6.—Full-grown larva of *Culex*.
Enlarged (author's illustration).

in the summer of 1898 it was so spread to a shocking extent has been demonstrated by the army typhoid fever commission. And the remedy is plain. It consists of two courses of procedure: (1) Proper care of excreta; (2) the destruction of flies.

Measures to be taken to prevent typhoid fever.—On many farms where intelligent people live the old-fashioned box privy has been

done away with, and there has been substituted for it some form of earth closet. Where a good earth closet is in operation, and the inhabitants of a farm appreciate the importance of using no other, and where in case of illness the excreta of patients are promptly disinfected, flies breeding in the neighborhood will have practically no opportunity to become contaminated with typhoid germs, except in the unlikely event (which future investigation may possibly show) that other animals than man are subject to this disease. The proper maintenance of an earth closet will add somewhat to the work of a farm, but this extra work will pay in the long run. While it is true that a box inclosure, if its contents are covered with lime every three or four days, will answer the purpose, a much better plan would be to use a large metal vessel, the surface of the contents being

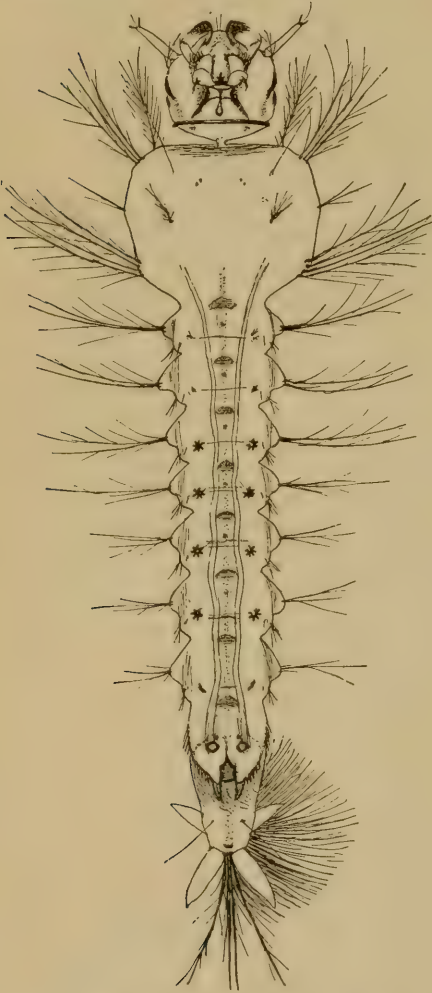


FIG. 7.—Full-grown larva of *Anopheles*. Greatly enlarged (author's illustration).

covered with earth after each operation, and which may be removed, emptied, and replaced daily. Care should, of course, be taken to empty the contents of the vessel in a pit constructed in some well-chosen spot, from which the drainage would not be dangerous.

With regard to the abolition of flies, the best measures will again naturally involve some trouble and expense. In a thickly settled country it will become necessary for some such measure to be generally adopted in order to be perfectly effective, but in an isolated farm-

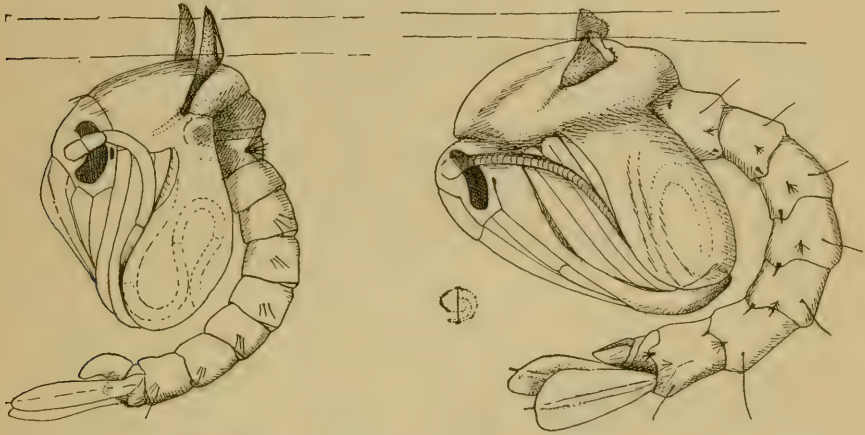


FIG. 8.—Pupa of *Culex* (at left) and *Anopheles* (at right). Greatly enlarged (author's illustration).

house the number of house flies may be greatly reduced by individual work. All horse manure accumulating in stables or barns should be collected, if not daily, at least once a week, and should be placed in either a pit or vault or in a screened inclosure like a closet at the side or end of the stable. This closet should have an outside door from

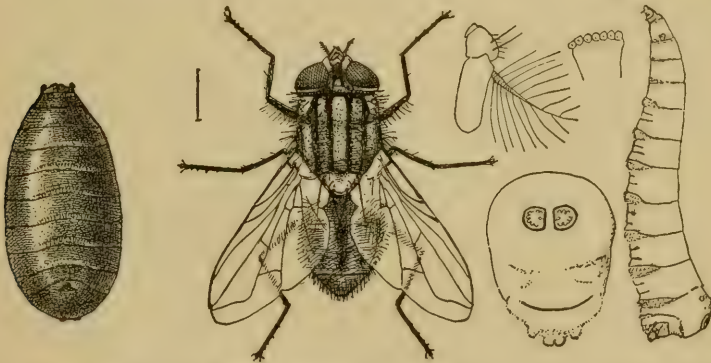


FIG. 9.—Common house fly (*Musca domestica*): Puparium at left; adult next; larva and enlarged parts at right. Enlarged (author's illustration).

which horse manure can be shoveled when it is needed for manuring purposes. Each day's or each week's accumulations, after they are shoveled into the closet or pit, should be sprinkled over the surface with chloride of lime, and a barrel of this substance can conveniently be kept in the closet. If this plan be adopted (and these recommen-

dations are the result of practical experience), house flies will have almost no chance to breed, and their numbers will be so greatly reduced that they will hardly be noticeable. Many experiments have been made in the treatment of manure piles in order to kill the maggots of the house fly, and the chloride-of-lime treatment has been found to be the cheapest and most efficacious.

It has been stated above that the closet for the reception of manure should be made tight to prevent the entrance or exit of flies. A window fitted with a wire screen is not desirable, since the corroding chloride fumes will ruin a wire screen in a few days.

Fruit flies.—While extended investigations have shown that the common house fly is the fly most to be feared in guarding against typhoid, on account of the fact that over 99 per cent of the flies found

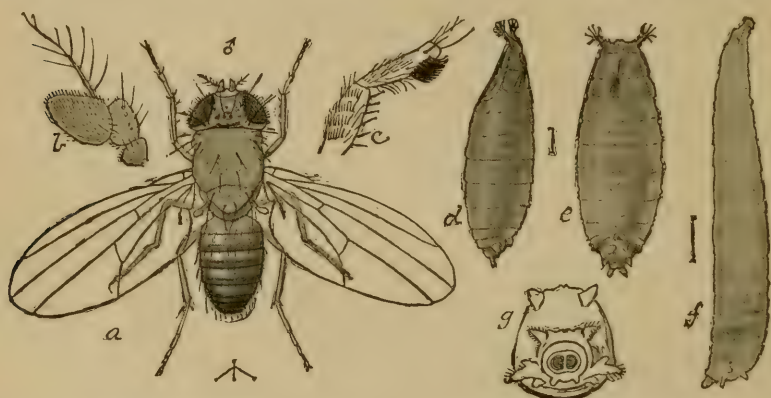


FIG. 10.—*Drosophila ampelophila*: a, Adult; b, antenna of same; c, base of tibia and first tarsal joint of same; d, puparium, side view; e, puparium from above; f, full-grown larva; g, anal spiracles of same. Enlarged (author's illustration).

in kitchens and dining rooms and attracted to food supplies are house flies, there are a few others which are attracted to and which may breed in human excrement that also have to be guarded against, and as these do not breed in horse manure the treatment just described will not be effective against them. The care of human excrement, however, will prevent the carriage of typhoid germs even by these species. The little fruit flies of the genus *Drosophila* (fig. 10), which breed in overripe or decaying fruit, are the principal species in this category. Therefore, fruit storehouses or fruit receptacles should be screened, and overripe fruit should not be allowed to remain in dining rooms or kitchens for any length of time.

OTHER DISEASES CARRIED BY INSECTS.

While in malaria and typhoid we have the two principal diseases common to the United States which may be conveyed by insects, the

agency of these little creatures in the transfer of disease germs is much more widespread in warm countries, and it is by no means confined to human beings. In Egypt and in the Fiji Islands there is a destructive eye disease of human beings the germs of which are carried by the common house fly. In our Southern States an eye disease known as pink-eye is carried by certain very minute flies of the genus *Hippelates*. In certain tropical countries a disease known as filariasis, which somewhat resembles certain forms of leprosy, is transferred among human beings by certain mosquitoes. There is good reason to suppose that the germs of the bubonic plague may be transferred from sick people to healthy people by the bites of fleas (fig. 11). The so-called Texas fever of cattle is unquestionably transferred by the common cattle tick (fig. 12), and this was the earliest of the clearly demonstrated cases of the transfer of disease by insects. In Africa a similar disease of cattle is transferred by the bite of the famous biting fly known as the tsetse fly (fig. 13) and the so-called

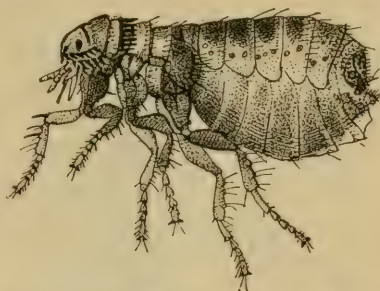


FIG. 11.—Cat and dog flea. Enlarged (original).

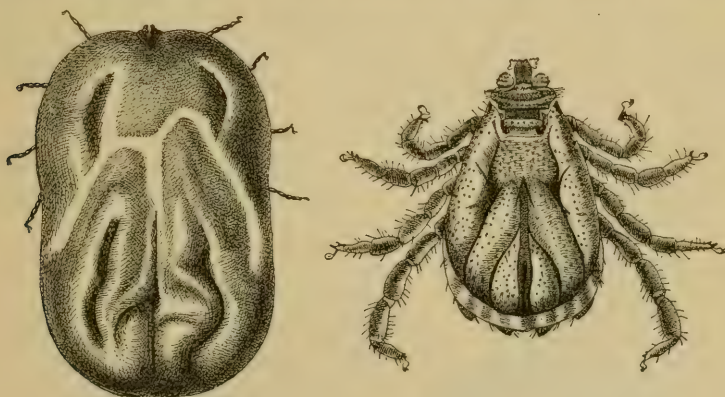


FIG. 12.—Cattle tick. Enlarged (redrawn from Salmon and Stiles).

“sleeping sickness” of human beings is conveyed by the same insect. The germs of the disease of cattle known as anthrax are carried by gadflies, or horse flies, and when these flies subsequently bite human beings malignant pustules may result (see fig. 14 for one of these gadflies); and other discoveries of this nature are constantly being

made. Even the common bedbug (fig. 15) is strongly suspected in this connection.

YELLOW FEVER.

One of the most important of these disease-transfer relations of



FIG. 13.—Tsetse fly. Enlarged (original).

insects which has been demonstrated is the carriage of yellow fever by certain mosquitoes. The cause of yellow fever has always been a mystery, and indeed it is a mystery to-day in a measure, since, although undoubtedly a disease of parasitic origin, the parasitic organism itself has not yet been discovered. During the summer and autumn of 1900 and spring and summer of 1901 the work of a com-

mission of surgeons of the United States Army demonstrated in Cuba beyond the slightest possible doubt that yellow fever is not conveyed by infected clothing of yellow-fever patients or by contact



FIG. 14.—Black gadfly. Enlarged (original).



FIG. 15.—Bedbug. Enlarged (after Marshall).

with such patients or by proximity to them, but that it is conveyed by the bite of a certain species of mosquito known as *Stegomyia*

calopus (fig. 16), which abounds in regions where yellow fever is possible. The bite of this mosquito, however, does not convey yellow fever to a healthy person until twelve days have elapsed from the time when the same mosquito has bitten a person suffering with the disease. It follows from this fact that by keeping yellow-fever patients screened from the possibilities of mosquito bites we can prevent the yellow-fever mosquito from becoming infected. It follows further that by preventing healthy people from being bitten by mosquitoes we can keep them free from the disease even where infected mosquitoes exist. And it follows still further that by the adoption of remedial measures looking toward the destruction in all stages of the yellow-fever mosquito we may reduce to a minimum the possibilities of the transfer of the disease. After demonstrating the fact, the medical officers of the Army in Cuba put these measures into effect, and the results were most gratifying. The health of Havana immediately im-



FIG. 16.—*Stegomyia calopus*. Enlarged (author's illustration).

proved, and the general health of Cuba and the industrial conditions dependent upon better sanitation have continually gained since.

The New Orleans outbreak of yellow fever in the summer of 1905 was quickly stopped by antimosquito measures, and it is conceded that more than 4,000 lives were saved in that city during that season by the intelligent application of measures based upon the discovery of the United States Army surgeons in Cuba in 1900 and 1901.

U. S. DEPARTMENT OF AGRICULTURE.

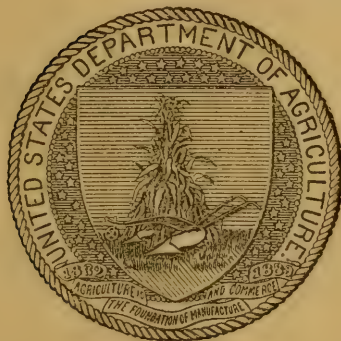
FARMERS' BULLETIN No. 163.

METHODS OF CONTROLLING THE BOLL WEEVIL.

[Advice based on the work of 1902.]

BY

W. D. HUNTER,
SPECIAL FIELD AGENT.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., January 6, 1903.

SIR: I transmit with this a brief manuscript by Mr. W. D. Hunter, a special agent of this Division in charge of experimental work with the Mexican cotton boll weevil (*Anthonomus grandis*). I have examined this manuscript and warmly approve of its recommendations. I urge its immediate publication as a Farmers' Bulletin.

Respectfully,

L. O. HOWARD, *Entomologist.*

HON. JAMES WILSON,
Secretary of Agriculture.

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METHODS OF CONTROLLING THE BOLL WEEVIL.

INTRODUCTORY.

The Division of Entomology has worked with the boll weevil since the first appearance of the pest in Texas in 1894. Up to the present time practically continuous observations have been made upon its natural history, habits, and the means by which it reaches new regions; and the results of these observations, with suggestions regarding the manner of combating the pest, drawn from them and from the experience of many planters, have already been published. It was not, however, until the last season that the funds at the disposal of the Division permitted experimental field work on a considerable scale. By special appropriation, which became available on the 4th of June, 1902, it became possible for the Division to conduct field work on a large scale and according to a system that gives tangible and presentable results. The arrangement consists of a contract whereby certain planters agree to plant, cultivate, and care for the crop exactly in accordance with the directions of the agent of the Division. It consequently gives the Division practically complete charge of large tracts of cotton in typical situations without involving the labor and expense of renting the land and working the crop. In this way 200 acres at Calvert and 150 acres at Victoria, Tex., were used for experimental purposes. A complete field laboratory was established at the latter place for rearing work, breeding parasites, and testing poisons, as well as investigating every feature of the life history of the weevil that may afford any advantage in fighting the pest.

Though somewhat handicapped by the late date at which the appropriation became available, the work of the past season has demonstrated many important points. The principal ones are presented in the following pages, together with such previously acquired information as constitutes, it is believed, the basis of a practical and effective system of producing the staple anywhere that the boll weevil occurs.

TERRITORY AFFECTED.

Though still confined to Texas, the territory occupied by the cotton-boll weevil (*Anthonomus grandis* Boh.) at present includes about 28 per cent of the cotton acreage in the United States. This acreage in

1900 produced 34 per cent of the total crop of this country, or one-fourth of the crop of the world for that year. As will be seen from the accompanying map (fig. 1), this region is bounded on the north

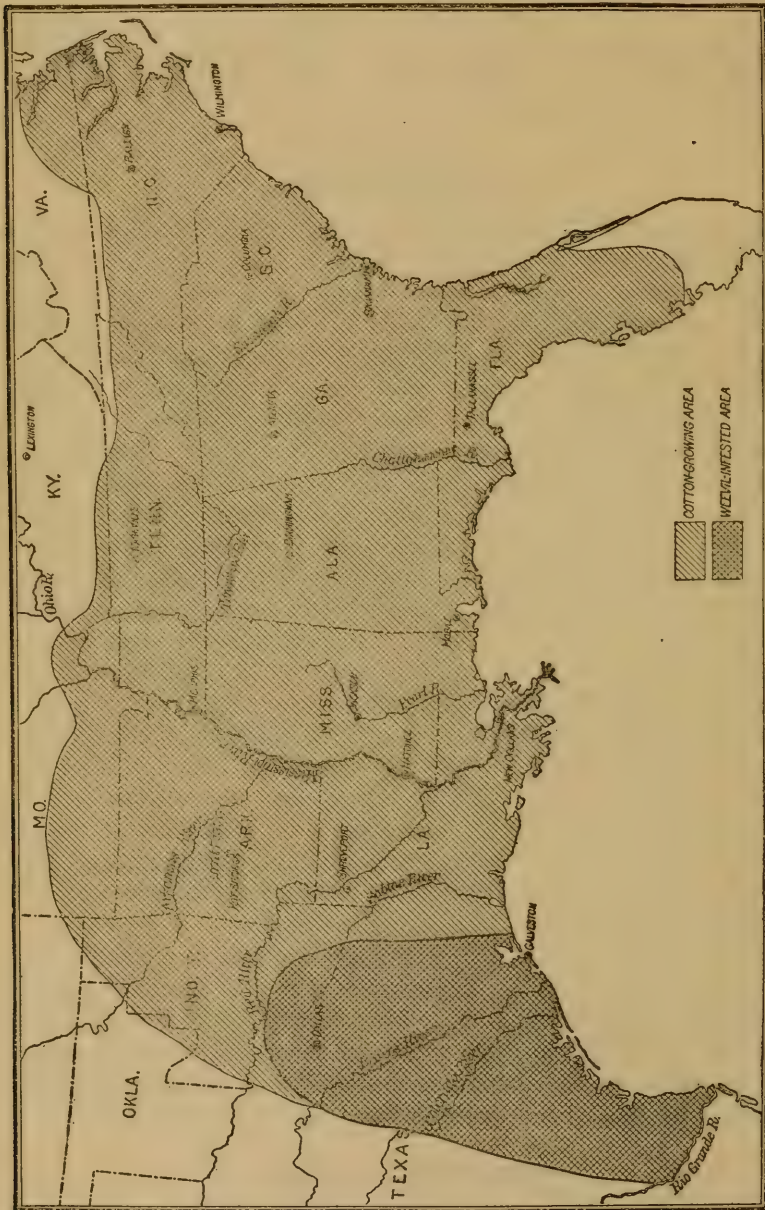


FIG. 1.—Map showing cotton-growing area and weevil-infested area.

by the Red River and on the east by the pine forests of the divide between the Trinity and Sabine rivers. It includes all of the 22 counties, which, in 1899, according to the Twelfth Census, produced

40,000 bales or more each. In the newly invaded region, however, between the latitude of Dallas and the Red River, the insect, though scatteringly present, has not multiplied to such an extent as to cause much damage.

AMOUNT OF DAMAGE.

Various estimates of the loss occasioned to the cotton planters during the past year have been made. They range from 235,000 to 500,000 bales, representing from 8 to 25 millions of dollars. In the nature of the case, such estimates must be made upon data difficult to obtain, and in the collection of which many errors must inevitably occur. As is well known, there is a general tendency to exaggerate agricultural losses, as well as to attribute to a single factor damage that is the result of a combination of many influences. Before the advent of the boll weevil into Texas, unfavorable weather at planting time, summer drought, and heavy fall rains, as well as the attack of many other noxious insects, caused very light crops to be produced. Now, however, the tendency is to attribute all of the shortage to the weevil. Nevertheless, not only on account of the very serious work of the insect, but also on account of the rather unfortunate previous condition of the cotton-producing industry, the boll weevil is among the most formidable menaces to an agricultural industry that ever arose in this country or elsewhere. It seems well within the bounds of conservatism to state that during 1902 the insect caused Texas a loss of at least 10 millions of dollars.

In spite of the generally serious outlook, it must be stated that fears of the damage the weevil may do are often, especially in a newly invaded district, very much exaggerated. It is by no means necessary to abandon cotton. The Division of Entomology has demonstrated the past season that the crop can be grown profitably in spite of the boll weevil. Moreover, the experience of many counties in south Texas shows how a locality can, in a short time, adapt itself to the new system of cotton raising made necessary by the weevil. The experience of Victoria County illustrates this point well. The following table shows the production of cotton since the advent of the boll weevil. No accurate statistics of acreage are available, but it is the uniform testimony of the most reliable planters that the acreage has not been increased very materially.

Cotton production in Victoria County, Tex., and in the United States, in equivalents of 500-pound bales.

Year.	Crop of Victoria County.	Crop of United States.	Year.	Crop of Victoria County.	Crop of United States.
	<i>Bales.</i>	<i>Millions of bales.</i>		<i>Bales.</i>	<i>Millions of bales.</i>
1894.....	6,895	10.5	1898.....	7,006	12.1
1895.....	4,404	7.5	1899.....	5,517	9.9
1896.....	9,796	9.2	1900.....	11,956	11.1
1897.....	7,746	11.9	1901.....	9,060	9.5

Besides showing in general a successful continuation of cotton culture in Victoria County since the weevil reached it, the above table indicates that the crop of the United States at large has varied year by year in much the same way as has the crop of Victoria County, showing that climatic conditions affecting the entire cotton belt have been a much more important factor than the weevil in reducing the crop in a series of years.

FUTURE PROSPECTS.

The most serious aspect of the situation is in the fact that the pest is constantly spreading and will undoubtedly eventually be distributed all over the cotton belt. There are no influences that can check it short of the limit of its food plant in this country. In Mexico, where the insect has existed as an important enemy of cotton for a much longer period than in the United States, the investigations of the Division of Entomology, as well as of the Mexican Government, indicate that the only factor in limiting its distribution is that of altitude. In the famous "Laguna" district in that country, including portions of the States of Coahuila, Chihuahua, and Durango, the weevil has never gained a foothold, notwithstanding the fact that large quantities of seed cotton are annually shipped there for ginning and milling from the lower region, where it is very numerous. That this region, under these circumstances, has never become infested seems only to be explained by its altitude, which is disastrous to an insect which probably originated in a region of very low elevation. The average elevation of the "Laguna" district is about 3,500 feet above sea level. Unfortunately, in this country there is no land at all adapted to cotton culture in the belt as now constituted that approaches such an elevation.

Basing the estimate on a careful study of the annual increase in territory since the insect reached Texas, as well as upon considerable attention that has been paid to the means whereby it reaches new territory, it seems safe to predict that in from fifteen to eighteen years the pest will be a serious drawback to cotton culture everywhere throughout the South, as it is in Texas now.

METHODS OF COMBATING.

It is wholly beyond possibility that the weevil is ever to be exterminated. Its history in Mexico and since reaching Texas, as well as the history of many related injurious insects, offers no hope that it will ever be much less destructive than now. Nevertheless, it has been demonstrated that cotton can be grown profitably by means of a few expedients in planting and managing the crop where the insect is present. These expedients involve no appreciable extra expense in producing the staple, and accordingly are coming to be generally

adopted in preference to direct means, such as poisons and machines, which, aside from their doubtful utility under many conditions, involve expenses for labor or material that soon hopelessly reduce the margin of profit.

During the past season the Division of Entomology has been engaged in field experiments to demonstrate that cotton can be produced successfully in spite of the boll weevil. Some of this work was conducted on the plantation of Col. E. S. Peters, in the Brazos Valley, near Calvert, Texas. This valley is, on account of its low and moist situation, the presence of timber, and the almost exclusive production of cotton, the most seriously affected portion of the weevil territory. In fact, the most favorable conditions possible for the multiplication of the insect are there present, and Colonel Peters's plantation is a typical one.

The accompanying diagram (fig. 2) shows the location of some of the experimental fields. The soil is the typical alluvial deposit of the valley and practically identical throughout the 128 acres included in this experiment. The seed was the ordinary seed of the region, grown on the same plantation the year before, of an unknown variety, as is usually the case in that region. The stand was equally good everywhere. No means of fighting the weevil whatever, aside from those mentioned, were practiced. In none of the fields did any other insects, aside from the weevil, cause any considerable injury. The bollworm was present, but did very little damage; the sharpshooter was scarcely noticed; and the leaf worm did not appear in sufficient numbers to warrant poisoning.

To summarize the results of these experiments:

1. Early planted cotton with thorough cultivation produced two-thirds of a bale per acre.
2. Early planted cotton with careless cultivation produced one-ninth of a bale per acre.
3. Early planted cotton with fair cultivation produced one-half bale per acre.
4. Late planted cotton with wide rows yielded about one-fourth of a bale per acre.
5. Late planted cotton with narrow rows, sprayed thoroughly, yielded about one-fourth of a bale per acre.

The evident conclusions are:

First. A profitable crop in the most unfavorable situation can be produced by early planting and thorough cultivation, as in Field I (fig. 2). This field produced one bale to 1.5 acres; the average production in the United States is one bale to 2.3 acres. The experiment, moreover, was performed during probably the most generally disastrous season for cotton culture in Texas for twenty-five years.

Little Brazos River

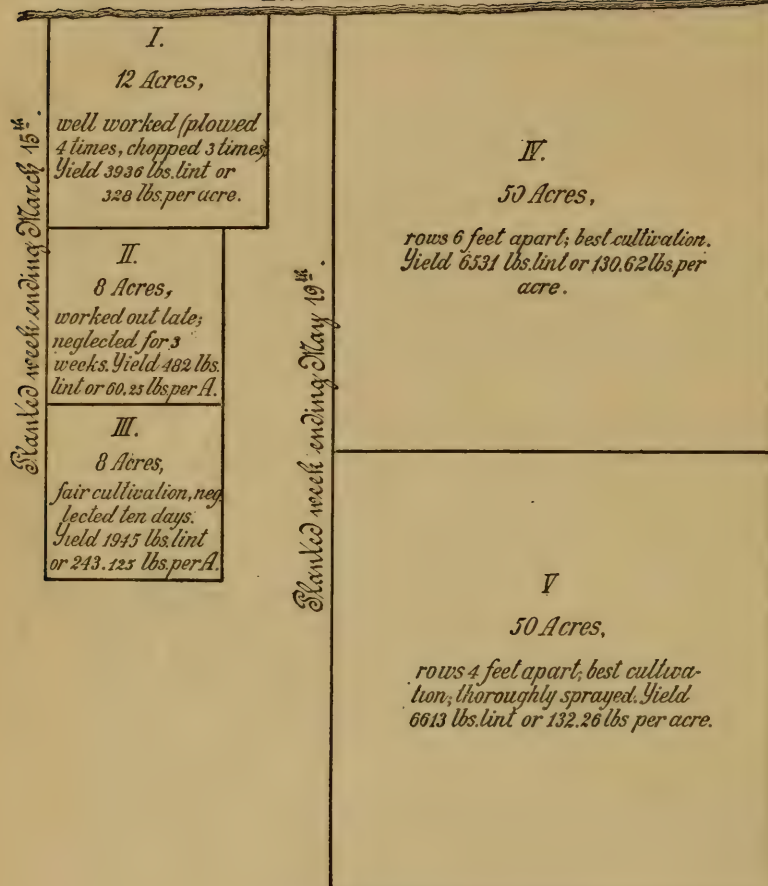


FIG. 2.—Experimental cotton fields.

NOTE.—Although the field of 50 acres with the rows 6 feet apart yielded less lint than the field of 50 acres with the rows 4 feet apart, the margin of profit was greater on the former on account of the saving in chopping. A tabular statement follows:

Yield on 50 acres with rows 4 feet apart.....	pounds..	6,613
Yield on 50 acres with rows 6 feet apart	do.....	6,531
Yield in favor of narrow rows	do.....	82
Value of excess at 8 cents per pound.....		\$6.56
Cost of chopping 50 acres with rows 4 feet apart, at \$1.25 per acre		\$62.50
Cost of chopping 50 acres with rows 6 feet apart, at 85 cents per acre		\$42.50
Saving in favor of wide rows		\$20.00
Saving in cost of chopping wide rows		\$20.00
Value of gain in lint in narrow rows		\$6.56
Actual gain in favor of wide rows		\$13.44

Second. Early planting not followed by thorough cultivation is of no avail, as illustrated in case of Field II (fig. 2). From this comes the important suggestion that planters should exercise the greatest care to avoid allowing a tenant more land than he can cultivate thoroughly. "Overcropping" would destroy all the benefit of early planting.

Third. The bad effect of late planting can not be remedied by wide spacing, by subsequent thorough cultivation, nor by spraying. But, nevertheless, late planting with thorough cultivation is better than early planting with careless cultivation, as is shown by comparing the results in Fields IV and V with those in Field II (fig. 2).

Fourth. In case the main crop can be planted early, the trouble and expense of planting trap rows for the weevil is entirely unnecessary.

Without going fully into details, it can be said that the work of the Division of Entomology has demonstrated several other very important points. Among these is the fact that the use of Northern seed and the seed of especially early-maturing varieties will increase the advantage of earliness in planting. It is very likely that in Field I, by using certain seed, the yield could have been brought up to at least three-fourths of a bale to the acre.

At Victoria early fall destruction of the plants the preceding year was found to bring about a very noticeable decrease in the number of weevils. For instance, as late as October 10, in a field upon which plants of the previous year had been destroyed by September 20, about 33 per cent of the squares were uninjured, while on fields in similar situations, planted about the same time, but upon which the plants had not been destroyed in the fall, it was impossible to find a case where more than 8 per cent of the squares were uninjured at that time.

It was also shown at Victoria that the weevils caused less damage in cotton planted only moderately early (week ending March 10) on land upon which the plants of the preceding season had been destroyed by burning early in the fall than in fields planted late (week ending April 30) on land that had never been in cotton and which, moreover, were measurably isolated from other cotton fields.

There are two methods of destroying the plants, namely, grazing, and burning after uprooting by plowing. There are three important general difficulties in the way of grazing: (1) It is not at present feasible in the portions of Texas where the bulk of the cotton crop is produced on account of the small number of cattle present; (2) in fields where Johnson grass is starting, cattle, by spreading it, would probably do much more harm than good; and (3) in many fields the nature of the soil, if tramped upon by cattle, would make it impossible to carry on thorough cultivation the following season. But burning the stalks by October 1, thereby preventing the maturing of many fall

broods as well as destroying many weevils that take refuge in the windrows as soon as the plants are uprooted, is feasible, effective, and economical, and consequently should be generally practiced.

The tendency of some planters to allow the plants to stand in the field, in the hope of securing a top crop, is one of the most serious obstacles in the fight against the weevil. The statistics as well as the testimony of the most experienced cotton planters in Texas show that there has not been any appreciable top crop produced in Texas in more than three years in the past quarter of a century. It is, therefore, safe to state that the gain to the planter the following season in a lessened number of weevils will always more than compensate him for the loss of any top crop he is likely to obtain.

The Department's experiments show that the matter of spacing the rows is rather uncertain. The distance depends upon the nature of the soil and the variety of the cotton grown. Moreover, much depends upon the season. During a very wet year plants will grow to such an extent as to make the greatest feasible distance unimportant from the weevil standpoint. In this matter the planter must always act in accordance with the experience he has had upon his land. It will be well, however, to bear in mind that the distance between plants in the row is fully as important as the distance between the rows. The nearer the soil area to each plant approaches a square, the greater the yield will be. At the same time, too great spacing, besides decreasing the yield, actually delays the fruitage, and is, therefore, especially to be avoided. As nearly as a rule can be formulated, it may be stated that on the river bottom soil, which produces the bulk of the Texas crop, a distance of $5\frac{1}{2}$ feet between the rows in a series of years would not be too great, while there are very few upland fields where 4 feet would be too great. A point in this connection that is frequently overlooked is in the great saving of labor when the rows are wide. For instance, it costs about one-third less to crop a field with rows 6 feet apart than one with rows 4 feet apart.

INEFFECTIVE METHODS OF COMBATING THE WEEVIL.

In order to save the cotton growers useless expenditure of time and means, attention is called to certain ineffective methods of combating the boll weevil.

NOSTRUMS.

Several specifics in the form of poisons for the destruction of the boll weevil have been widely advertised. At the laboratory in Victoria these have all been tested and found absolutely useless. The weevil being an insect that in all stages except one feeds well protected in the square or boll, and takes nourishment in the remaining stage

almost exclusively by inserting its beak well within the tissue of the fruit, will never be reached by such means. It can not be stated too emphatically that money paid for these ingeniously advertised substances is wasted.

In this connection it may be stated that there is no known variety of cotton that is immune against the attack of the boll weevil, notwithstanding the advertising claims of certain seed dealers. The only advantage one variety can possibly have over another is in point of early maturity.

MACHINES.

Many attempts have been made to perfect a machine that will assist in destroying the weevil. The Division of Entomology has carefully investigated the merits of representatives of all classes of these, beginning in 1895 with a square collecting machine at Beeville that had attracted considerable local attention. Up to the present time, however, none of these devices has been found to be practicable or to offer any definite hope of being ultimately successful. The difficulty and expense of working a machine when most needed, as in very wet weather, will probably always prevent them from coming into use. If it were not possible to raise cotton profitably without the use of a machine, the situation would be materially changed. But since it is possible, as is shown in this bulletin, to produce the staple without the use of any other means than those that enter into cotton culture everywhere, there seems no hope for these machines. If perfected at all, they will undoubtedly meet the same fate as the many complicated devices for destroying or poisoning the cotton-leaf worm with which planters and entomologists were especially concerned about twenty years ago, the wrecks of which may now be found upon any of the older plantations in Texas.

COTTON-SEED MEAL.

Recently the report has been circulated that cotton-seed meal exerts a powerful attraction for the weevil, and that they may consequently be killed easily by mixing poisons with it. This report seems to gain credence in some quarters, and unfortunately may reach as wide circulation as did the fallacious theory propounded last July that mineral paint would kill the pest. The Division of Entomology has experimented exhaustively, not only in the laboratory but in the field, with cotton-seed meal and finds that it is totally useless. In the laboratory weevils were confined in cages with meal and squares and in other cages with meal and cotton leaves. In no case during continuous watching for several days was a weevil found leaving the squares or leaves to feed upon the meal. In the field, sacks of meal were placed in five different cotton fields where weevils were plentiful;

examinations were made daily for eleven days, but only a single weevil was found on the meal, and that one seemed to be merely seeking the protection of the sack. During the eleven days many weevils were caught and placed upon the sacks of meal, but in no case were they found there the next day. It is difficult to see how a more forcible demonstration of the futility of cotton-seed meal as an attractant for the weevils could be presented.

EGYPTIAN COTTON AND THE BOLL WEEVIL.

Peculiar circumstances surrounding one of the Department's experimental fields of Egyptian cotton at San Antonio gave rise during the past season to a belief that such cotton is exempt from injury by the boll weevil. Unfortunately this mistaken idea was in some way accredited to the agents of this Department. The resulting interest is still manifested in frequent letters received from planters regarding the obtaining of "immune Egyptian seed."

As a matter of fact, numerous observations made during 1901 and 1902 on several varieties of Egyptian cotton growing at different places, show that they are particularly susceptible to damage by the boll weevil. In fact they are much more likely to be injured than the ordinary varieties of American upland cotton. The tendency of the varieties of Egyptian cotton observed, including Mitafifi and Jannovitch, is to grow a very large stalk. Absence of irrigation does not appreciably modify this tendency. Egyptian cotton is therefore invariably late in maturing, setting no bottom crop. Late cotton, wherever grown, is certain to be injured by the weevil. There is nothing in the plant distasteful to the insect, which in Mexico has been found working in tree cotton and in Texas in sea-island cotton, both as far removed botanically from American upland as is Egyptian. In the field at San Antonio by the middle of September the pests had increased to such an extent that every square was punctured, and the consequent absence of the preferred places for oviposition had driven them to many bolls that had previously given promise of developing. A few volunteer American upland plants growing among the Egyptian ones, though only $3\frac{1}{2}$ feet in height, produced more of the staple per plant than did the surrounding Egyptian plants $5\frac{1}{2}$ feet high.

SPECIFIC RECOMMENDATIONS.

The work of the Division of Entomology for several years has led to the recommendations which follow. It has been demonstrated in the experimental fields of the Department and by the experience of many cotton planters that by using these simple means a profitable crop can be produced in any situation where the boll weevil occurs:

I. Plant early. Plant, if possible, the seed of the varieties known to

mature early, or at least obtain seed from as far north as possible. It is much better to run the risk of replanting, which is not an expensive operation, than to have the crop delayed. The practice of some planters of making two plantings to avoid having all the work of chopping thrown into a short period is a very bad policy from the boll weevil standpoint. Taking a series of years into consideration, it will not be found too early to plant cotton in the latitude of Houston and southward by the 25th of February; in the Brazos Valley, as far north as Waco, by the first week in March; and at no place in northern Texas later than about the 20th of March.

II. Cultivate the fields thoroughly. The principal benefit in this comes from the influence that such a practice has upon the constant growth and consequent early maturity of the crop. Very few weevils are killed by cultivation. Much of the benefit of early planting is lost unless it is followed by thorough cultivation. In case of unavoidably delayed planting the best hope of the planter is to cultivate the field in the most thorough manner possible. Three choppings and five plowings constitute as thorough a system of cultivation as is necessary in most cases.

III. Destroy, by plowing up, windrowing, and burning, all the cotton stalks in the fields not later than the first week in October. In some cases turning cattle into the fields is advisable. Aside from amounting to practical destruction of the plants, grazing of the cotton fields furnishes considerable forage at a time when it is generally much in demand.

IV. Plant the rows as far apart as experience with the land indicates is feasible and thin out the plants in the rows thoroughly.

In addition to these specific recommendations it may be stated that anything that can be done in the way of protecting birds, like the quail, which are known to feed upon the weevil, will undoubtedly be of advantage.

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The following is a list of the Farmers' Bulletins available for distribution, showing the number, title, and size in pages of each. Copies will be sent to any address on application to Senators, Representatives, and Delegates in Congress, or to the Secretary of Agriculture, Washington, D. C. The missing numbers have been discontinued, being superseded by later bulletins.

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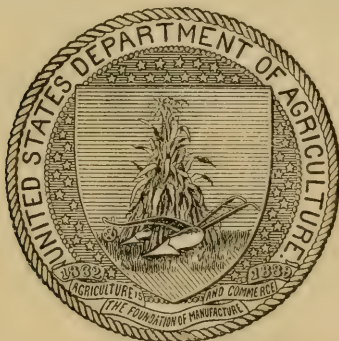
FARMERS' BULLETIN No. 165.

SILKWORM CULTURE.

BY

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Special Agent in Silk Investigations, Division of Entomology.



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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., March 5, 1903.

SIR: I transmit herewith an article on silkworm culture, prepared by Miss Henrietta Aiken Kelly, special agent in silk investigations of this Division, and recently published as Bulletin No. 39 (new series) of this Division, to which has been added a few paragraphs of information on the culture of the mulberry, condensed from Bulletin No. 34 of the Bureau of Plant Industry.

Miss Kelly has studied the culture of the mulberry silkworm as carried on in France and Italy for a number of years, has consulted the works of the best European authorities, and is therefore well qualified for this task. Although the silkworm industry has not attained much commercial importance in the United States, there is a popular demand for information on the subject which, it is believed, can be supplied to the best advantage by the republication of this matter in the popular Farmers' Bulletin series.

Respectfully,

L. O. HOWARD,
Entomologist.

Hon. JAMES WILSON,
Secretary of Agriculture.

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SILKWORM CULTURE.

The caterpillars of many moths and of a few butterflies produce silk, but certain of those belonging to the family Bombycidae, or true silk-spinners, particularly *Bombyx* (*Serica*) *mori*, or the mulberry silkworm, yield the most and the best silk. The races of *Bombyx mori* to-day are the result of domestication and artificial rearing, and the wild type is uncertain, though most authorities assign the foot of the Himalaya as the cradle of the mulberry silkworm. It has been industrially cultivated in China from time immemorial, and in Europe since the sixth century.

THE LIFE OF THE SILKWORM.

Like all insects of its class, before arriving at the perfect winged state, it exists (1) as a caterpillar or larva, and (2) in a chrysalis state.

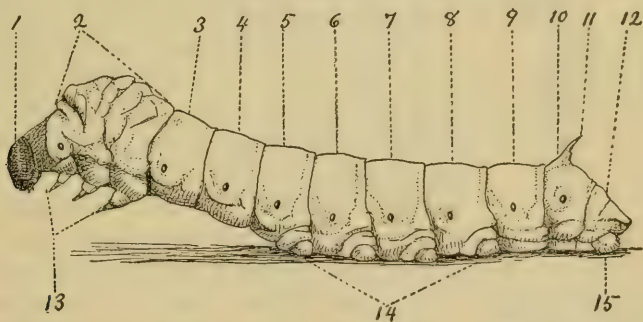


FIG. 1.—Adult silkworm: 1, head; 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, rings; 11, horn; 13, 3 pairs of articulated legs; 14, 4 pairs of abdominal or false legs; 15, a pair of false legs on the last ring.

THE LARVA, OR CATERPILLAR.

The larva (fig. 1) has a cylindrical body composed of 12 rings; each of the first three has a pair of jointed legs, and the sixth, seventh, eighth, ninth, and twelfth each bears a pair of false legs, destined later to disappear.

The black elliptical spots on the side are the orifices for breathing, and are called stigmata or spiracles.

The head is a small mass covered with a hard scale, and is provided with jaws that move laterally, like the wings of a folding door. The alimentary canal extends throughout the entire length of the body,

and on each side of it is placed a silk gland (fig. 2). These consist of two whitish or amber-colored cords, which after innumerable curves unite in the spinneret in the region of the mouth. There are also two glands, whose excretory canal opens in the spinneret, and covers the silk as it comes out with an impermeable varnish rendering it insoluble in acids and alkalies. This varnish is about a fifth of the weight of the thread.

Hatchings usually occur annually in the spring. Simple contact with the air causes the new-born insect immediately to acquire a volume larger than it had in the egg, and it quickly begins to gnaw the under surface and edges of the mulberry leaf. It eats day and night at all hours, except when asleep, and in about thirty days grows 14,000 times larger than it was at birth.

As the silkworm grows larger it becomes paler in color, because its dark chestnut brown hairs are scattered over a larger surface, thus showing more of the true color of the skin.

About five days from its birth the vitality of the larva decreases, and it eats scantily or not at all, and becomes thin and whitish in color. Then it moves around unquietly, and finding a convenient place attaches itself to it, holding on by its false feet. It thus remains motionless, with the front part of its body raised up, for a period of time varying according to temperature, and takes its first so-called "sleep," or molt, during which time the body undergoes extraordinary modifications. The skin is entirely shed, and all the tissues that can not keep up with the rapid growth of the insect are changed.

The scale which covers the snout is the first part of the case to fall, and a new case appears under the former one. The worm then pushes

itself forward through its first ring, sets at liberty the legs of the thorax, and by a wriggling movement comes out of its old sheath.

To facilitate this difficult change a liquid is secreted between the old skin and the one forming beneath it.

The life of the larva is usually divided into four ages, varying in length according to temperature, frequency of feeding, race, and the robustness of the worm. The following is about the average:

First age, from birth to first molt, five to six days.

Second age, from first to second molt, four days.

Third age, from second to third molt, four to five days.

Fourth age, from third to fourth molt, five to seven days.

Fifth age, from fourth molt to maturity, seven to twelve days.

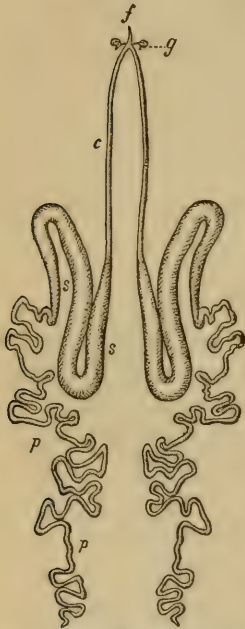


FIG. 2.—Silk glands in a mature worm: *p*, portion of glands which secrete the silky matter; *s*, reservoir; *c*, conducting canal; *f*, spinneret; *g*, accessory glands (redrawn from Verson and Quajut).

Some time after each molt, perhaps the time needed to regain lost strength and to solidify the newly-formed organs, the worm remains in a state of relative torpor. Not much practice is needed to recognize when it has come out of its "sleep." It moves its head and thorax, which are whitish, while the rest of the body is gray, and has completely lost the shining aspect which it had when the worm began to molt. When fairly through its first molt the larva begins again to eat, and its hunger does not cease until it is ready for a new molt.

Four molts having been made, the worm eats a prodigious quantity of leaf until it reaches its maximum growth, when its appetite diminishes and ceases altogether. It then stops moving and remains for some time in repose, evacuating, meanwhile, its digestive canal, thus losing up to 12 per cent of its weight. Its lean body is now white or yellow, according to the race, and semitransparent.

Very soon it begins to move about again, lifts up its head, which is longer and more pointed, and turns in every direction seeking to find a convenient angle, finding which, it throws out a silk thread from its spinneret. First a net is formed to hold the cocoon which is to be spun, then the regular spinning begins and the form of the cocoon is designed. For some time through the veil which very soon is to surround it, the diligent larva, with its back turned outward, may be seen completing its task. It is calculated that with its head alone the silkworm makes 69 movements every minute, describing arcs of circles, crossed in the form of the figure 8 (fig. 3, *a*).

Meanwhile the web grows closer and the veil thickens, and in about seventy-two hours the worm is completely shut up in its cocoon, which serves it as a protective covering.

THE CHRYSALIS.

In the cocoon the silkworm goes through the last phase of its larval life. After four or five days the skin breaks, and the insect which

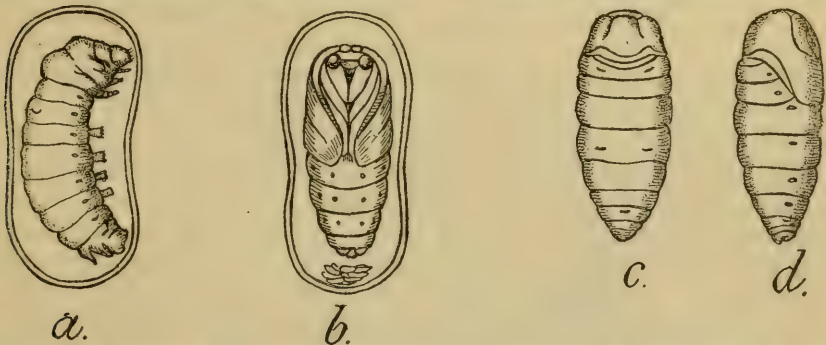


FIG. 3.—The chrysalis: *a*, silkworm completing its cocoon; *b*, cocoon and chrysalis—cast-off skin of larva beneath; *c*, back view of chrysalis; *d*, side view of chrysalis. (Redrawn from Maillot.)

issues from this old covering is the chrysalis, whose weight is often only half that of the larva at its highest development (fig. 3)

The chrysalis seems to have neither head nor feet, is golden-colored at first, and then turns chestnut brown. The skin dries rapidly and forms a hard case, on which the lines of only the posterior rings are seen, the place of the first three rings being covered with the wing-cases.

The chrysalis state is in certain respects a sleep and in others a period of great activity, in which the entire being is transformed. Wings, antennæ, reproductive organs, and legs are all now developed. This state lasts from eighteen to twenty days, according to the temperature. When the metamorphosis is complete, the sheath breaks in the region of the head and the moth or perfect insect issues.

THE MOTH.

The larva in spinning the cocoon leaves one end less dense, so that the threads open freely to permit the egress of the moth. By the aid of an alkaline fluid the moth softens and parts the threads and liberates itself.

The moth (fig. 4) comes out of the cocoon, as the larva out of the egg, in the early morning hours. It has a distinct head, thorax, and abdomen, four wings, two comb-shaped antennæ, three pairs of legs, and a pair of compound eyes.

Shortly after emerging, the moth deposits a liquid substance, generally white, sometimes colorless and sometimes reddish, and then the union occurs, lasting several hours, after which the eggs are laid either immediately or in the course of four or five hours.

A gelatinous substance supplied by two glands near the extremity of the oviduct covers the eggs as they come out, and causes them to adhere to the substance on which they are laid.

The laying, consisting of 300 to 700 eggs, is generally completed in three days, 70 to 80 per cent being deposited the first day, 20 to 30 per cent the second day, and a few the third day. The mother moth dies six to twelve days later, her death being usually preceded by that of the male. Death occurs more or less speedily, according to the robustness of the moth, the temperature, and the tranquillity in which it has been left.

Thus in about sixty-five days the silkworm has completed its cycle of existence, its three periods being thirty to forty days in a larval

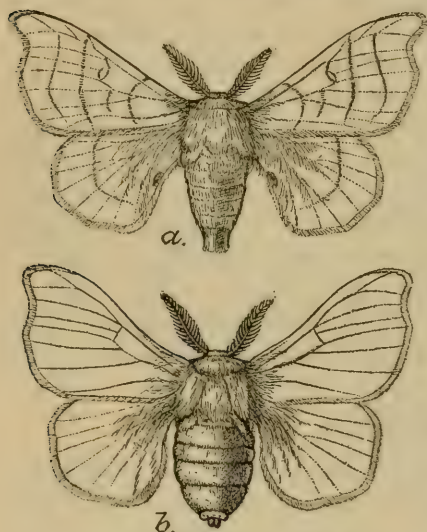


FIG. 4.—The moth: *a*, the male; *b*, the female.

state, fifteen to twenty days as a chrysalis, and eight to twenty days as a moth or perfect insect.

The rapid development of the silkworm and its marvelous transformations indicate extraordinary power and very active functions. Its respiration is almost equal to that of the frog and of certain large birds, and it must be always surrounded by plenty of pure air.

THE FOOD OF THE SILKWORM.

The leaf of the white mulberry is the natural and the best food for the silkworm. There are many varieties of the white mulberry—some much better adapted than others to commercial silk culture, and some better suited to certain localities.

CULTURE OF THE MULBERRY.

As the securing of a food supply is a necessary condition to silkworm culture, some information on the culture of the mulberry, condensed from a bulletin of the Bureau of Plant Industry, ^a is inserted:

Of the mulberry there are many so-called species and a great many varieties, but there are only one or two species and a few varieties which are of importance in silkworm propagation. Chief among these for producing silkworm food is the white mulberry, *Morus alba*. This is thought by some to be a native of China. It is hardy over a large area of the United States.

Most of the silkworms reared in China are said to be fed upon *Morus multicaulis*. This mulberry was largely planted in the United States many years ago. Few, if any, of the original trees remain, but specimens which are thought to be wild seedlings of these are very plentiful in the Southern States. These trees are thoroughly acclimated and free from disease. It is therefore probable that there is now in the United States an abundant supply of material for propagating purposes, at least. The white mulberry, under good cultivation, is a low-growing tree, seldom attaining a greater height than 25 or 30 feet. It will reach this height in a comparatively few years after planting. In the vicinity of Washington the trees flower about the middle of May and ripen their fruit during June.

The mulberry may be propagated by means of seeds, cuttings, layering, grafting, and budding. Seeds and cuttings are, however, the least expensive and troublesome, and the most satisfactory means of propagation.

Propagation by Means of Seeds.—This is the most convenient and rapid method of propagation. To remove the seeds from the berries, place them in a large bucket or a tub and squeeze them with the hands until they form a jelly-like mass. Add water and stir well to allow the seeds to sink to the bottom. The water and pulp can then be poured off, and the seeds can be dried by exposure to the air.

The seeds may be planted at once, or they may be kept over winter and planted in the spring. Beds about 5 feet wide should be thoroughly prepared. The seed should be sown broadcast, not too thick, as crowding makes weak plants. Press the seeds in with the back of a spade and cover lightly with fine soil. For protection from the heat of the sun, over the beds should be placed lattice-work screens made of lath, and over these canvas should be spread until the plants show above the ground. After that the canvas is unnecessary except in the hottest part of the day. With spring-sown seeds the lath screens without canvas will be sufficient.

^a Bul. No. 34, Bureau of Plant Industry, U. S. Department of Agriculture. By George W. Oliver.

Seedlings vary considerably from the parent tree, and many of the seedlings grown will be found to have leaves of undesirable quality. Hence careful selection should be practiced and many of the seedlings must be rejected.

The Use of Cuttings.—For propagation by means of cuttings in the summer time, selected seedlings which have made considerable growth may be used. Two or three leaves clipped to half their length should be retained on the cutting (fig. 5, *a*.) The cuttings should be set sloping in beds of moist sand in a cool propagating house, or, if such is not available, in a cold frame with northern exposure; if in the shade of trees, so much the better. The sash should be kept closed to conserve the moisture of the atmosphere until the cuttings have taken root. When considerable root

growth has been made they should be transferred to beds in the open, being placed 6 inches apart each way and well watered until established.

The supply of winter cuttings should come from dormant wood taken from the trees just after the leaves have fallen. The cuttings (fig. 5, *b*) should not be less than one-fourth inch in diameter and should be about 10 inches in length, the top cut being made about a half inch above a bud. The cuttings should be tied in bundles of 50, and these may be buried in moderately moist sand or ashes until spring, when they can be put out in rows in well-prepared soil. These nursery rows should be well cultivated and kept clear of weeds.

Another method of propagation from cuttings, and a very successful one, consists in selecting medium-sized shoots about the beginning of November. These, before being made into cuttings, are sorted into bundles of different lengths, tied, and heeled in ashes or sand, or in a mixture of both, and protected by a frame having a northern exposure. During the winter they are taken out and cut



FIG. 5.—Mulberry cuttings: *a*, a summer cutting; *b*, *b*, winter cuttings.

into lengths of about 5 inches. These are tied in bundles and buried in moist sand or moss. In early spring they are untied and put quite thickly in a propagating bed having a mild bottom heat, where they will root rapidly. When such a bed is lacking, wooden flats about 4 inches deep may be used, but they must have the protection of a frame covered with sash. If a little loamy soil is placed in the bottom of the flats the cuttings will remain in good condition for a considerable time after rooting and until a favorable opportunity arrives for planting them out in nursery rows.

Planting.—The mulberry grows well in a great variety of well-drained soils. The young trees should be transferred from the nursery to their permanent places either

in the fall or in the spring. If in the fall, the transplanting should be done when the leaves have matured or fallen. In the spring transplanting may take place as soon as the ground is in good workable condition. The ground should be deeply plowed and thoroughly harrowed. If the ground is hard and the soil poor, large holes should be dug and filled with good soil as the trees are planted. In transplanting the roots should never be allowed to get dry. When taken up they may be immediately dipped in a mixture of soil and water and then kept covered until planted.

The distance between the trees should not be less than 10 feet each way. If the grove is to be large, wider spaces should be left at intervals, so that wagons may be driven through.

Pruning.—Pruning is best done in the fall or winter. The central part of the tree should be kept open to admit light and air. The low, spreading form of tree is much the best, and this form is secured by systematic pruning, which is begun by cutting the young tree back one-half in the fall after it is first planted out. Afterwards three or more strong shoots should be selected to form the main branches, and, if necessary, these may be prevented from growing upright by means of sticks fastened between them in such a way as to force them to spread apart.

In gathering the leaves always allow enough to remain on the tree to insure its perfect health. If some of the trees show signs of failing vigor as a result of excessive leaf gathering, it is advisable to allow them to grow for a season without picking, and by early pruning out of unnecessary growth permit those growths which are desirable to become ripened.

Restricting the height of the trunk of the mulberry to 5 or 6 feet makes it possible for old women and children to gather leaf, thus diminishing the cost of labor one-half, a most important point in commercial silk culture.

It is also important to cultivate trees that bear little or no fruit, for the production of fruit not only consumes part of the strength of the tree, but much labor is involved in being compelled to divest the branches of fruit before they can be used as food for silkworms.

The stump mulberry, or that growing low like a shrub, the hedge mulberry, and that which grows along walls vegetate much earlier than the medium and high trunk trees. Silkworm rearers should always have a ready supply of leaf for the first ages of the worm, and especially is this necessary if early cultures are desired with a view to escaping the heated days of May and June.

AMOUNT OF LEAF AND PREPARATION.

The race, the size of the worms, the variety and age of the mulberry, the nutritive quality of the leaf, the year, the season, and the climate make the requisite quantity of leaf very variable. The following is given as a basis of calculation, all circumstances being considered, and the leaves not being cleaned: For the larvæ hatching from 1 ounce of eggs, during the first age, 11 pounds of leaves; during the second age, 26 to 33 pounds; during the third age, 88 to 145 pounds; during the fourth age, 264 to 352 pounds; during the fifth age, 1,540 to 1,760 pounds; or about 2,200 pounds in all, of which one-half is consumed in the last six or seven days of the fifth age.

The age of the leaf should be relative to that of the worm. Young worms fed on old leaf, or old worms fed on young leaf, are apt to become diseased, and even though they may not die, will scarcely molt or will spin indifferently. A change of leaf, too, should, if possible, be avoided, or made gradually. Fresh leaf only should be used,

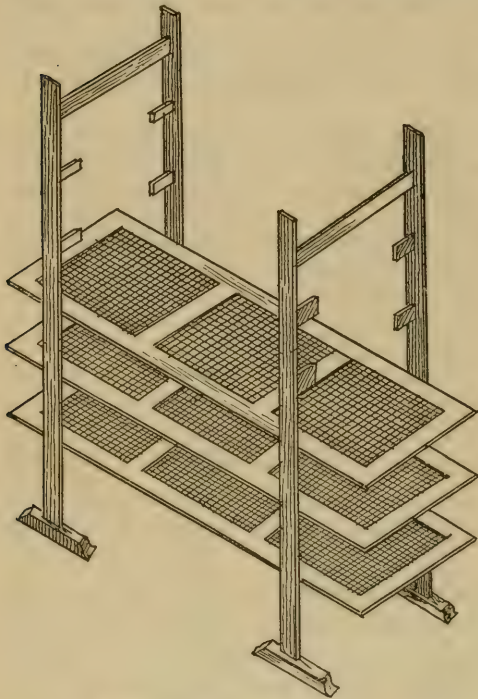


FIG. 6.—Light movable shelves.

and never when wet with dew or heated, or before it has in a measure acquired the temperature of the room in which the worms are being reared. It should be gathered early in the morning or in the evening and should not be bruised or torn, nor should the baskets or aprons used to carry it be the same which are used to remove litter. To avoid fermentation the leaves must be spread out in a cellar or cool, darkened room. Cut up only a limited quantity of leaf at a time and cover with a damp cloth to keep fresh, but never submerge the leaf in water, as this is apt to occasion flacherie, a very destructive disease. From the fourth age on

there should always be a day's supply ahead, so that in case of rain the worms will not have to fast.

In gathering leaf, always strip the branches from base to top, so as not to tear the bark and injure the new buds. The sacks for holding the leaves should have a hoop around the opening and a hook to suspend them to the branches.

IMPLEMENTS NECESSARY TO SILKWORM CULTURE.

Commercial silk culture requires a smaller outlay of capital than almost any other industry. The net gain the first year may pay for an outfit which will last for many years. The following articles are indispensable:

- (1) Some very light movable shelves, open to air, for the first ages; and, for the following ages, latticed shelves about $3\frac{1}{2}$ feet wide, and stands to support them.
- (2) Unsized ordinary wrapping paper or newspapers to cover the shelves.
- (3) A small ladder, if necessary, to reach high shelves.
- (4) Small trays to remove worms.

(5) Knives to cut leaves and baskets to distribute them.

(6) Coarse tulle and nets or perforated paper for changing beds and equalizing the worms.

(7) A supply of brush, straw, or shavings to construct the spinning place.

(8) A thermometer.

Wire, twine, laths, or canes are suitable for the lattice work of the shelves. Make the space between the shelves about 14 inches. If

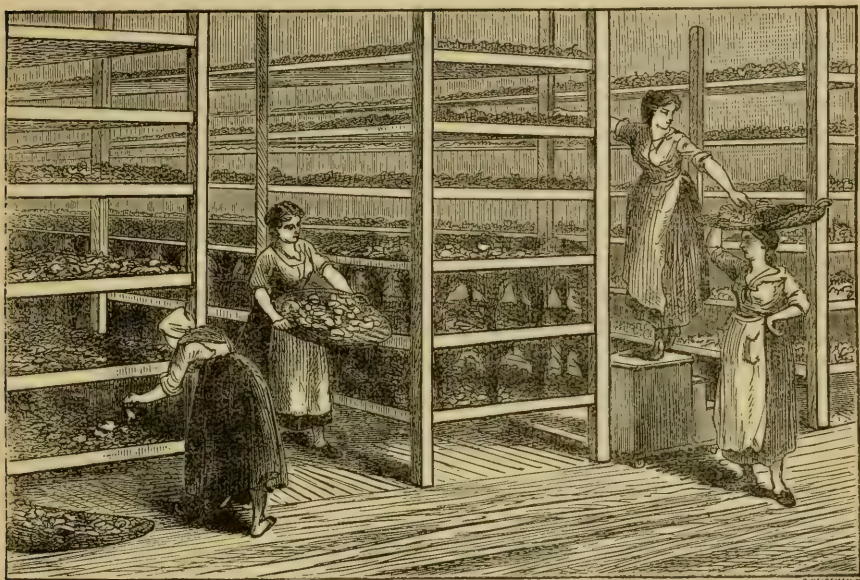


FIG. 7.—The rearing room (after Gobin).

possible, do not arrange the shelves along the wall, and allow a good passage between the tiers of shelves (figs. 6 and 7).

SILKWORM EGGS: HOW TO WINTER AND HATCH THEM.

There are two kinds of silkworm culture: One for production and one for reproduction. The object in the first case is to get the greatest yield of cocoons, and with a little training, may be carried on by anyone of ordinary intelligence.

The object in culture for reproduction is to secure eggs free from hereditary taint of disease, and experts only can be depended on to conduct it. Besides a careful physiological examination throughout the rearing, the body of the mother moth is microscopically tested after death, and her eggs are not retained if signs of disease are discovered. In this way the birth of healthy worms is insured. Pasteur first applied this method of selecting silkworm eggs, and thus checked the plague (pebrine) which was rapidly destroying silkworm culture in Europe.

Formerly, through an indiscriminate use of eggs, disease invaded the rearings to such a degree that from 65 to 90 pounds of cocoons was considered a good yield per ounce of eggs. At the present low price of silk such cultures are no longer remunerative, and industrial silk culture now demands the exclusive use of scientifically tested eggs.

The grainage, or preparation of eggs for market, constitutes a special department of silk culture. In Italy there are over 400 establishments which supply eggs to raise the annual silk crop. The poorest peasant, though well skilled in the art of rearing silkworms, would not risk a rearing with eggs which have not been selected and preserved by experts.

The eggs of crossed races are best for culture with a view to production of silk, and here, as much as in the examinations which have been referred to, the knowledge of experts is needed.

The life of the egg, in those races which have but one generation each year, has three phases, the first lasting about three months, full of activity; the second lasting from about October to the middle of February, one of inactivity, in which there are no signs of life; the third from the middle of February to the moment of hatching, in which the vital activity recommences, and the germ begins to organize as soon as the temperature rises a little above 50° F. The measure of the activity of the egg, in this stage, is the measure of its danger, for any sudden change of temperature would injure or destroy the delicate embryo, or cause the larva to be born before its food was ready. To guard against such accidents, eggs must be wintered in a high region or in a refrigerator at a uniform temperature of about 35° F., from December 15, until the mulberry begins to bud or until hatchings are desired. There should always be good ventilation, the air should not be moist, and great care must be taken to keep the eggs out of the reach of mice and insects.

Natural hatchings are almost always irregular, extending over eight or ten days, thus multiplying the divisions and rendering the rearing difficult and costly; hence, the necessity for artificial incubation.

Eighteen days before the time decided on for the hatching, spread out the eggs in thin layers in the incubating room or incubator. The temperature should be 55° F.

From the fourth day on, gradually increase the temperature two degrees in twenty-four hours until 73° F. is reached, when, at this uniform temperature, hatchings will occur in ten days on an average. This period, however, varies from eight to fifteen days, according to race, the cold supported during the winter, the first grade of heat, and the highest during the incubation, and the number of days taken to pass through these two grades of heat; and also according to the humidity. To obtain a good and complete hatching, a slight humidity

is necessary, especially during the last four or five days. To secure this keep an open vessel of water near the fire, or sprinkle the floor with water occasionally.

The temperature may be raised during the hatching to 75° F., but sudden changes of heat must be avoided, and, unless the newborn worms can be kept in the same temperature, it is dangerous to have the maximum temperature of the incubator so high.

It is better for the period of incubation to be protracted than suddenly shortened. Holding the eggs at a certain temperature, or slowly lowering the temperature a little does no harm. When the season is not propitious, the hatching may in this way be retarded.

An incubating room is preferable, because it also serves for the first two stages of the worms, but in small rearings an incubator is more economical, both with regard to service and to fuel.

For a large quantity of eggs (5 to 10 ounces) a small incubator, which is very much used in chemical laboratories to dry substances, is recommended. Any ordinary tinsmith can make it. It consists of a double case, cubical in form, with a zinc bottom. The space between the outer and inner walls is filled with water. The front face of the cube is furnished with a glass, so that the temperature within, indicated by the thermometer hanging on the glass, may be seen without the necessity of opening the incubator. There are two openings below on opposite sides to allow the cold air to come in, and an opening in the center of the top to permit the outward flow of the

heated air. Having filled the space between the walls with water through the pipe, the incubator is placed on a support and heated by means of a gas or oil lamp to the desired degree, and, by raising or lowering the flame, a constant or progressive temperature can be maintained (fig. 8). A self-regulating incubator, such as is used to hatch chickens, would be more convenient, but would cost more.

The whitening of the eggs denotes the near approach of the hatching. Double pieces of tulle or sheets of perforated paper sprinkled over with finely cut-up white mulberry leaves should then be lightly placed over the eggs to allow the outward passage of the worms as soon as hatched. The object in employing two pieces of tulle or paper is to prevent the unhatched eggs which cling to the sheet from being removed with the newborn worms. This process must be

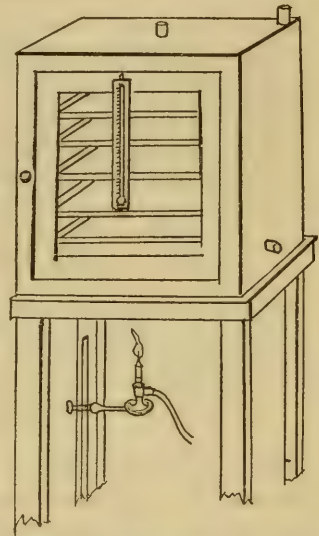


FIG. 8.—Hot water incubator. (Redrawn from Verson and Quajat.)

repeated daily during the hatching, the second sheet always being renewed.

The duration of the hatching varies from three to five days, the eggs hatching about as follows: During the first day, 5 per cent; during the second, 33 per cent; during the third, 50 per cent; during the fourth, 5 per cent; during the fifth, 7 per cent.

Twenty-five grams of eggs will give about 17 grams of worms. In small rearings most cultivators raise only the worms that are hatched on the second and third days, to avoid the necessity of forming too many classes. The worms must be classed according to the date of birth, and the insignificant number hatched on the first and last days scarcely compensate for the trouble of rearing them. Different races must also be reared separately.

Where several in one neighborhood are engaged in silk culture it greatly reduces the cost to have all the eggs hatched in one incubator. The person best acquainted with silk culture can undertake the incubation, and distribute the young worms on the second or third days to those who are to rear them. This is the plan adopted among the Italian peasantry, the wife of the supervising farmer hatching the eggs for whole villages.

THE REARING OF SILKWORMS.

Before entering into the details of a rearing some general directions must be given concerning the rearing room—the heating, ventilation, and disinfection.

GENERAL DIRECTIONS.

The place chosen for a rearing should be relatively high, and not exposed to malaria or bad odors, and mulberry trees should grow around it. Any room that can be properly heated and ventilated will answer the purpose. An open fireplace is the best means of heating, but is expensive, as much of the heat is lost. Hot-water pipes, such as are used to heat a greenhouse, are good for a building specially built for silkworm rearing. Iron stoves should not be used, unless placed in an adjoining room with communicating pipes. Never employ charcoal as fuel.

Ventilation.—The domesticated worm should be surrounded continually by pure air. The amount of carbonic-acid gas given out by the worms and their attendants is very considerable; besides this, a quantity of deleterious gas is generated by the litter of the beds, and the lights and fires consume a great deal of oxygen. Myriads of spores and germs of organic life float in the air of the rearing room, and their influence paralyzes the vital energy of the skin and of the organs of respiration, on whose normal functions the robustness of the worm so much depends. Hence, it is evident that the quantity of

vitiated air which should be expelled from the room requires the introduction of a large quantity of fresh air. For this, a double system of ventilation is necessary, which may be obtained by double openings in the windows, to allow the heated bad air to pass out above and the cool fresh air to come in below. To renew the air in every part of the room, and to avoid a single and often violent current, there should be more than one window. An open fireplace is the best means of ventilation. When the difference between the external and internal air is slight, or there is no difference at all, artificial means must be used to create a current. Light and frequent fires, or a burning lamp in the fireplace, or a revolving fan, may be used to prevent stagnation of the air.

Disinfection.—Eight or ten days before introducing the worms into their quarters all the shelves and implements should be washed in a solution of chloride of lime (11 pounds of chloride of lime to 88 quarts of water), or in a solution of sulphate of copper (1 to 100 by weight).

When everything is in order—tools, perforated paper, material for the worms to spin their cocoons on, etc., each in its own room—close the doors and windows as tightly as possible and fumigate the rooms with sulphur (11 pounds of sulphur to every 100 cubic yards of space). To fumigate properly, powder the sulphur and place it in an earthen or metallic vessel over a slow fire. The sulphur will gradually melt and take fire. Place it immediately in the rearing room and leave it, with the doors and windows completely shut, for twenty-four hours.

Nets should not be exposed to sulphur fumes, for this would soon rot them, but should be washed in a solution of sulphate of copper, and immediately afterwards in plain water.

Twenty-four hours after the fumigation the floors should be washed with a solution of chloride of lime or sulphate of copper, and the walls should be whitewashed with lime.

When dead worms are seen on the shelves, change the beds and create in the rearing room sulphurous gas by burning a pound of sulphur during six hours, or make a strong wood smoke, which is a good disinfectant and will not harm the worms.

Precaution having been taken to destroy germs of disease in the rearing room, the new-born worms may now be safely installed there.

Space Required.—The worms from 1 ounce of eggs should cover at birth 1 square yard. Doubling this space on the fourth day, they would require 2 square yards, and at their change of beds after molting, 4 square yards. By the spacing of the third day of the second age, and the doubling of beds preceding the second molt, they will need for the second age 8 square yards. For the third age 16 square yards will be required; for the fourth age 32 square yards; and for the fifth age 60 square yards. The more space that is accorded to the

worms in their first ages, the more robust they will be; and if the space can be tripled instead of doubled during the fourth age, and for the fifth age be 70, 80 or 90 instead of 60 square yards, the harvest of cocoons can be raised from 60 kilograms to 70, 80, or 90 kilograms per ounce of eggs, the quality of silk also being superior.

Temperature.—The silkworm is not a tropical insect, and attains its best development between the temperatures of 68° and 77° F. It is safe to adopt the mean between these two temperatures for the general rearing. Each cultivator, however, may suit his convenience, remembering that to fall below or to exceed the mentioned limits of heat is detrimental to the worm, and will affect the quantity and the quality of its spinning.

From the second age the temperature should be from 70° to 72° F. and should be kept as uniform as possible to the end of the rearing. The time which elapses between one change and the following one may be much shortened by raising the temperature and feeding oftener. Such hasty rearings may be made in twenty-two to twenty-four days. They are, however, to be condemned, as contrary to the nature of the silkworm. Meals following each other too closely can not be properly digested, and are likely to cause disease. Besides, hasty rearings require more labor, and the service must be kept up night and day. As there is danger in too high a temperature, so there is danger in one that is too low (64° to 68° F.). A rearing that is too prolonged, lasting over thirty-two days, is to be avoided to escape the heat of June, under which the beds are more likely to ferment, causing disease; the worms have less appetite and leave more leaf from one meal to another; the changes are slower and less likely to occur instantaneously; and there is more risk of muscardine or calcino, a disease due to a mold.

Both hasty and tardy rearings are, therefore, to be proscribed, and those conducted in twenty-eight to thirty-two days alone are recommended. This lapse of time permits the leaves of the mulberry to acquire maturity, and the growth of the worm should be relative to that of the leaf on which it feeds.

THE FIRST AGE.

Hatchings usually occur early in the morning. The worms which have crawled up through the holes of the tulle or paper to get food, should not be removed before 10 a. m. to the latticed shelves covered with paper to receive them. Each shelf must be marked with the date of the birth of the worms put upon it, and care must be taken to place on the same shelf only worms born on the same day, as a remunerative rearing demands that such alone be raised together.

Should the hatching occur at 68° to 70° F., keep this temperature during the first ages, and feed eight times during twenty-four hours; if

the temperature at birth is 75° to 77° ., slowly diminish the temperature one or two degrees, and feed ten times in twenty-four hours. The appetite of the worm increases or diminishes with the heat. The second day, in case of the worms hatched at the maximum, adjust the temperature to the degree proposed to conduct the rearing. In feeding sprinkle finely cut up tender leaves frequently over the worms, and toward the fourth day begin to regulate the number of meals so that it will range from four to eight, according to the temperature. Before cutting the leaf remove the stems. Distribute the leaf uniformly and equally on the shelves, in order to prevent the worms from crowding more on one side than another, and in order that they may be equally nourished and make their changes simultaneously. Cut only a small quantity of fresh leaf at a time, and keep the rest in jars or baskets covered with a damp cloth. Never submerge the leaves in water. For the first two or three ages, the white ungrafted mulberry is recommended, it being lighter and more digestible for delicate worms.

It is well during the feeding to open the door and windows to insure a good supply of fresh air. After feeding, close the door and windows, unless the day is warm, when they may be permanently left open, protected by curtains through which the air passes freely. The worms should never be exposed to direct sunlight or to a strong current of air, and during a thunderstorm the windows and doors should be closed.

Worms of the same age and development should be classed together. To obtain this equalization, do not feed newborn worms until all that have been hatched on one day have been removed to shelves, then give a general meal. If at the end of two or three days it is noticed that on certain shelves there are smaller worms than on others, in order to allow the less developed worms to catch up with the more advanced ones, place the former nearer the fire or on the highest shelves, where the air is warmer, and give them one or two more feeds than the larger worms. For this reason it is well to have light movable shelves.

Many cultivators of silkworms do not change the beds during the first age, and it is not absolutely necessary, if the leaf has been well cleaned of stems and very finely cut up, and, above all, if the air is dry. Change of bed, however, must be made if the litter is damp, and the weather rainy, for the worms are going to molt in two or three days, and this crisis should not occur in unhealthy conditions. It is always more prudent to change beds on the fourth day, and is, therefore, advised. The space occupied by the worms must be doubled when the change of beds is made.

The bed on which the leaf and excrement accumulate is, perhaps, the greatest source of danger to the worms. When there is not a free circulation of air, gases are developed which almost always cause fermentation, paving the way for future disease. Hence the necessity for frequent change of beds. This is made in various ways. The

practice of doing this by hand is to be condemned because it consumes too much time and is apt to injure the worms. Thread nets (fig. 9) and perforated paper are the best means to employ. They save two-thirds of the hand labor, and thus allow beds to be oftener renewed, which is a most important consideration. In the first age tulle or mosquito net may be employed instead of nets or paper.

The manner of proceeding is as follows: Place the last meal at night on the nets and extend them over the worms. By morning the worms will have mounted above the opening in search of fresh leaf. Then lift up the nets, beginning at the top shelf, and place them on clean shelves. Carefully detach from the nets any portion of the old bed, and, if the worms are not molting, gather up the few worms that have remained behind, and tenderly place them with the others. The change of beds is thus rapidly effected with the least labor.

It is very important that the tension of the net be such as to prevent the worms from being crowded together in the middle.

Perforated paper (fig. 10) is another means often used to effect change of beds; but it does not allow the worms to mount with the same facility. It is also apt to break when the worms become heavy, and in many cases it has to be renewed annually, so, in the end it is no cheaper than nets.

In changing beds, do not feed the worms that are first taken up until all from the old bed

have been removed; then give a general meal, for all the worms born on the same day and forming one class should have the same number of meals to preserve their equality of growth, which is necessary for a successful rearing.

Having adopted hours for feeding, these should be adhered to throughout the rearing. When four meals are given, the best hours are 5 to 6 a. m., 10 to noon, 3 to 6 p. m., and 9 to 11 p. m.

Toward the sixth day worms begin to eat less. This is a sign that they are going to molt. Then another change of beds and doubling of space are necessary.

The molt or change of the worm is easily recognized by a swelling of the head, whitening of the skin, transparency of the body, and a fixed position.

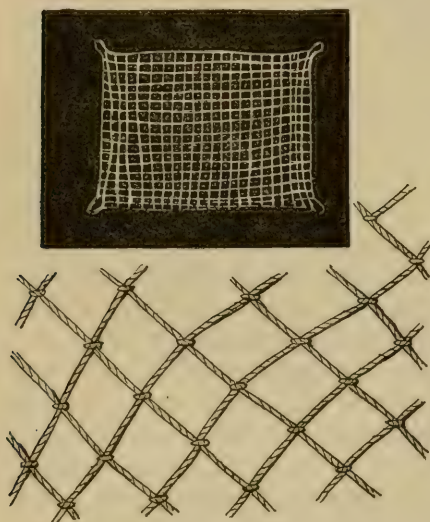


FIG. 9.—Net used in changing beds.

To change the beds, proceed as before, only leave undisturbed on the old beds the worms that are molting. When all the tardy worms have been taken up and placed on shelves, give them frequent sprinklings of finely cut up leaf to enable them to catch up with the worms already molting. Diminish the feeding as the backward worms begin to molt, and cease feeding entirely as soon as a single worm comes out of the molt. Then wait twenty-four hours so that the worms may be well over the change before giving a general feed. In this way the equality of development necessary for a methodical and successful rearing is maintained. A fast of twenty-four hours will not hurt the advanced worms, while the extra feeding given to the backward ones may enable them to become equal to the former.

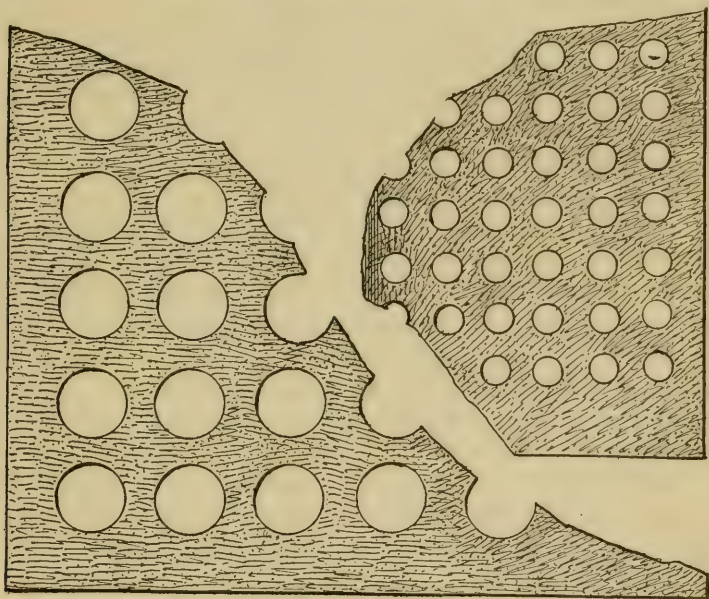


FIG. 10.—Perforated paper used in changing beds in the second and third ages.

The beds or the worms on the old litter may be changed when the general meal is given.

Many cultivators do not change the beds and double the space until after the first molt, allowing all the worms to change in the same bed. In this case, owing to the distribution of leaf for one or two days after the molting has begun, the molting worms are covered by a more or less thick coat of litter, and exposed to emanations of bad gases in a critical period of life, which is likely to cause disease. Besides, in the first age, the worms are so small that they are likely to be lost in the litter, or to perish from suffocation. Hence, it is healthier to change beds and double the space before the molt.

THE SECOND AGE.

The coming out of the molt is announced by the appearance of a small triangular-shaped livid spot on the worm's head, and the changed skin is grayish in color. The worm takes several hours to recover from a change; then it begins to search for food, which, however, as before stated, must not be given before all the worms have recovered from the molt. Then a slight meal is given by means of perforated paper or nets. The worms crawl up promptly and can be easily gathered up and placed on fresh shelves.

If the two sets of worms recover from their molt at the same time, they may be classed together; if there is a difference of a day, it will be necessary to keep them separate throughout the rest of the rearing, for the equality of age has disappeared, and, if they are put together, the second change will not occur simultaneously for all the worms, but will extend over several days, and occasion the greatest trouble to reestablish the equality of size necessary for the best results.

In case no worms have had change of bed before the molt, do not recommence feeding until the greater part of the worms are awake. Do not fear that they will suffer from hunger. Then form a new division of those still molting. It is frequently better to have two divisions, but if, to simplify the work, but one is desired, by putting the backward worms on the highest shelves, and feeding them oftener than the advanced set, an equality may be reestablished.

Three days after the first molt the beds must be renewed, and at the same time more space must be allowed the worms.

The second age is the shortest, being less by two or three days than any of the others. Toward the fifth day of this age the worms begin to molt again. Then act as before—that is, by aid of nets or perforated paper, remove the backward worms, in order to place them elsewhere, and try by more heat and abundant food to make them catch up with the forward worms.

THE THIRD AGE.

When the worms are over their second molt they cease to be gray, and take the characteristic color of their race. If they are too long in molting it is because the temperature is too low; that is, below 68° F. Increasing the heat a few degrees will excite the worms and enable them to complete their change. After this the temperature adopted for the rearing must gradually be resumed.

The worms double their size in their third age; consequently the space allotted to them must be doubled; that is, they must have 16 square yards instead of 8 square yards, as in the second age.

From the second to the third molt the same care is to be given as has been prescribed for the first two ages, except that, if a small incubating room has been used instead of an incubator, the worms must

now be transferred to a larger room to complete the rearing. Care must be taken to heat this room the day before to 80° F., and the next day lower the heat to the degree adopted for the rearing. Feed six times daily either with whole leaves or leaves which are coarsely cut up. For this as well as all the other ages the best rule to follow in feeding is to give only a light sprinkling of leaf at the beginning and end of each age, gradually increasing the ration up to the middle of each age, and then diminishing to the time of a molt. The appetite of the worm will serve as a guide. Give more or less leaf according as the preceding meal has been more or less eaten. In this way leaf will not be wasted and a large quantity of litter will not accumulate under the worms, to their detriment.

Toward the sixth or seventh day of the third age, according to the temperature, the worms begin to be languid and lose appetite, as before, and are ready to make a third change. This is the most difficult of all and the one in which they seem to suffer the most. It is also the period when diseases due to bad eggs or to a poor incubation are developed. Excepting accidental diseases, a good result may generally be predicted if the third change is safely passed. With these facts in view, from the beginning of the third age keep the worms sparse on the shelves and see that the beds are dry and changed with scrupulous care, the litter being far removed from the rearing room. Avoid feeding with wet leaf, and to favor the molting raise the temperature a degree. It will be noticed that the head and body of the worm are more swollen than in other molts. It is this superabundance of liquid that renders this molt so critical and necessitates a drier atmosphere and a bed which is very dry and not apt to ferment.

The worms increase three times in volume after the third molt, and must have space accordingly. They must be separated into three divisions in the following manner: Instead of waiting, as in the first two changes, until half of the worms have begun to molt, let down the nets, or otherwise prepare for the removal of the backward worms when one-third or even less of the worms show signs of molting. About two-thirds will then crawl up on the fresh leaves, and must be placed on a shelf where, after one or two meals, they proceed to molt, being again divided after the first or second distribution of leaves, according to the rapidity of the molting.

If only a few worms mount when the first division is made, the operation was delayed too long, and it is unnecessary to divide those first taken up; but after the change the division of those left on the old bed can be made. To allow the worms to spread out, each division should occupy but one-third of the shelf on which it is placed.

THE FOURTH AGE.

When all the worms have molted the third time a change of beds must be made as in preceding ages. Do not be in haste to change.

Wait a few hours to permit the worms to recover their strength a little. The recommendation to feed lightly at first applies especially to the beginning of the fourth age.

If the outside temperature is normal, fires need not be kept up, and the doors and windows may be left open, guarded by light curtains. In this age the worms eat enormously and more help will be required to gather and distribute leaf. Small branches of leaf may now be given in place of whole leaves, and the number of meals may be reduced to four, if the temperature is 68° to 70° F., at which temperature the age will last nine days. If it is desired to reduce this age to seven or eight days, raise the heat to 72° F., and give five or six meals daily. Should change of weather retard the growth of the mulberry trees, and temporarily cut off the supply of leaf, adapt the rearing to such a contingency by lowering the temperature slowly to 66° or 68° F., and giving only three or even two meals daily. Then, when leaf is obtained, gradually raise the temperature to the degree adopted for the rearing.

During the fourth age four changes of beds are made, including the one which follows the third molt. A single division of the worms is sufficient, which will be the last, and particular care must be taken to divide the worms into two equal parts. For this, spread the nets or perforated paper over the worms when half are molting and proceed as before.

THE FIFTH AGE.

Do not be in haste to change beds as soon as the worms have molted. This precaution is necessary to allow the new organs to acquire consistency, and to prevent worms from being lost in the litter. Consequently, wait several hours, and change beds after the second meal, the first being only a slight sprinkling of leaves. Worms are not strong enough immediately after a change to digest a heavy meal.

The space during this age should not be limited. See that between two worms another could be easily placed. Experience has proved that the harvest of cocoons is often in proportion to the space accorded to the worms during this age.

Feed from four to six times daily, according to the temperature, and spread the branches or leaves out regularly, not to form a mass. For a simultaneous mounting into the brush all the worms should eat an equal quantity of food.

As ripe berries are very indigestible, and also cause beds to ferment, care must be taken to shake the trees well before gathering the leaves, and whatever ripe fruit remains must be taken off before feeding.

If possible, change beds daily, especially if more than five meals are given, or if the weather is very warm and damp and there are signs of disease.

The first five days after the change the worms grow enormously, and it is very difficult to satisfy their appetite. At the end of this

time the body suddenly diminishes in circumference, the excrement, formerly dry and firm, now becomes moist and soft, and the appetite diminishes and becomes capricious. This state generally lasts three days, then suddenly the worm ceases to eat, and tries to get away from its food. It prolongs its head, and, changing its former lazy habit of scarcely moving except to get food, runs about in every direction, stopping from time to time, and moving its head (now transparent gold or white, according to race) like a blind person seeking the way.

These signs indicate that the worm is hunting a convenient place to spin its cocoon. The worm is now mature, and a spinning place should be ready to facilitate its metamorphosis. The humidity, which always exists at this time on account of the mass of litter, is especially dangerous to the worms; and it is increased if the worms do not all mature and mount at the same time, for those that remain below are wet by the liquid dejections of those that are the first to mount. For this reason do not put worms in the spinning place until they are perfectly mature. They then mount, and crawl around some time seeking a favorable place for their cocoons. Finding this they evacuate their digestive canal, and begin to throw around them an irregular net in which the cocoon spun later will be suspended.

PREPARATIONS FOR SPINNING.

A considerable loss may occur in the spinning place even when the rearing has been most successful. To avoid such loss observe the following precautions: (1) Prepare the spinning place in time; (2) arrange it so that the worms may regularly mount, and have abundant room; (3) have it well made, yet economical; and (4) regulate the heat and ventilate the room.

Any convenient dry bushy brush, odorless and free from gum, will serve to construct the spinning place; or if such is not available, bundles of straw, or shavings, or finely split up wood may be substituted. The best and most economical arrangement is small bundles of brush or straw placed upright between the feeding shelves, in rows, about 16 inches apart. The bundles are cut a half inch taller than the space between the shelves, and their tops are spread out to form arches, and to allow the worms plenty of room to spin (fig. 11).

Branches of elm, oak, birch, etc., are used to place the worms in the spinning place. These branches are spread over the shelves at the end of the fifth age. Very soon they will be covered with mature worms which have ceased to eat, and are turning away from the mulberry. In this way it is easy to select the worms that should be transferred.

If the worms are equally developed, in thirty or forty hours they will be shut up in their cocoons. The few that remain behind should be placed elsewhere; fed with fresh leaf on clean beds they will soon catch up with the others.

The fifth day after the mounting the worms that have not begun to spin should be placed in bundles of twigs and covered with straw or leaves, or put in a basket of shavings, where they will be forced to spin.

The temperature during the spinning should be 75° F., and the humidity throughout the rearing about 65° . A good practical test of

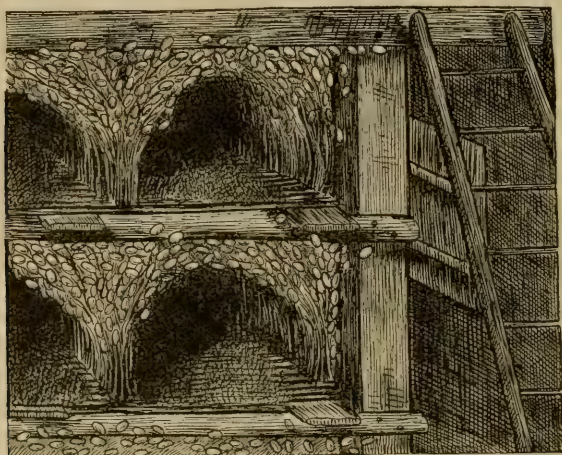


FIG. 11.—Arrangement of spinning places. (Redrawn from Pasteur.)

humidity is a saucer of salt; when the salt is moist, reduce the humidity. Carefully avoid disturbing the worms while spinning, and then, as during all the ages, keep the room as quiet as possible. The most scrupulous cleanliness should always be observed, both with regard to the quarters and the attendants; to keep from raising dust, wipe the floor with a damp cloth instead of sweeping it.

PREPARING COCOONS FOR THE MARKET.

The transformation of the larva into the chrysalis is, according to the temperature, completed in from seven to ten days from the time at which the first worm begins to spin. The cocoons are then said to be mature, and this is the best time to gather them. If gathered earlier, the producer will run the risk of having his cocoons rejected in the market; and if later, he will sustain a very sensible loss in their weight, as they grow lighter from the time of their maturity until the moth comes out. The best authority estimates the minimum loss as 4.1 per cent, and the maximum as 23.3 per cent. To avoid the risk of soiling them, gather the cocoons from the lowest shelf up. They may be freed from the web or floss by a very simple instrument (fig. 12) or by hand.

After the removal of the web the cocoons are sorted into three classes: (1) The perfect, (2) the double, and (3) the defective or

spoiled. They are then spread out in 4-inch layers, on clean shelves, in an airy, dry room, not exposed to sunlight, and very carefully guarded from rats, mice, and insects. The defective and discolored ones are put in a separate room.

The thread of a cocoon is continuous with that of the web, and diminishes in diameter within. Its length varies from 1,200 yards to 1,600 yards, and its value accordingly. Different races, sexes, and conditions of rearing often produce notable differences in weight of cocoons. Thus the weight may vary from 155 to 320 cocoons to the pound (340 to 700 to the kilogram).

Often two or more worms are inclosed in the same cocoon. Cocoons formed from such collaboration are larger than single ones, irregular in form, and cottony in texture. They can not be unreeled, and consequently are far less valuable than single ones.

The proportion of silk in a cocoon varies according to the race and the régime to which the worm has been subjected. The average normal cocoon at the time it is sold is thus composed:

	Per cent.
Water	68.2
Silk	14.3
Web and veil	.7
Chrysalis	16.8

If the cocoons are not sold as soon as gathered, the chrysalides should be killed without delay unless they are to be reserved for reproduction. Otherwise the moths may pierce the cocoons, thus rendering them unfit to be reeled.

The chrysalides are usually killed either by heat or suffocation. The means most commonly employed are (1) the heat of the sun; (2) hot dry air in a stove; (3) hot humid air in a stove; (4) steam; (5) oil of turpentine; (6) carbon bisulphid or some other gas. Probably the best of these means are steam at a temperature not above 212° F. applied without pressure, or hot damp air at a temperature of 196° F.

The killing of the chrysalides is an important operation and one requiring care and judgment. If some are left alive, the moths will issue, thus rendering the cocoons of little value. On the other hand, if the operation is continued too long, the silk may be injured. The best methods are those in which the heat is carefully controlled and excessive dryness is avoided.

The following is a very simple and easy way to destroy the chrysalides by the use of steam:

Place a cauldron of water on a stove. When boiling begins set over the cauldron a white hollow wooden cylinder, about 3 feet high and 2 feet in diameter, with

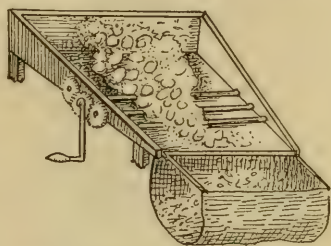


FIG. 12.—Device for removing floss from cocoons. (Redrawn from Nenci.)

a perforated bottom and open at the top. Arrange in this cylinder round baskets three-fourths filled with cocoons; then cover the cylinder with a perforated lid. In about thirty minutes the operation will be completed, after which remove the cylinder, take out the baskets, and spread out the cocoons to dry before storing, to prevent them from spoiling.

Mr. T. A. Keleher of this office has adopted the following plan:

The cocoons are placed in an air-tight box of about 24 cubic feet capacity; about half an ounce of bisulphid of carbon in a small dish is placed in the box and left over night. It is best to open one or two of the cocoons to find if the chrysalides are dead; if not the operation must be repeated. Care should be exercised that no fire of any kind be brought into the vicinity during this operation as the bisulphid of carbon is very inflammable.

In shipping cocoons care must be taken to pack them in baskets or cases permeable to air, but sufficiently close to keep out rats and mice, which are very destructive to cocoons.

DISEASES OF SILKWORMS.

In every successful rearing of an ounce of eggs about 40,000 worms are hatched, and 30,000 succeed in spinning cocoons. The rest either die from casual wounds or from diseases incidental to restricted action. But sometimes whole chambers are destroyed by hereditary and contagious diseases, and it is of supreme importance to cultivators to learn how these scourges may be avoided.

In this limited treatise only a bare mention can be made of the most fatal diseases and of the necessary precautions to be taken to guard against them. The general cause of disease is the domestication of the worm. By using good eggs, however, and following the methods which are actually employed by successful rearers, remunerative results are usually obtained. To obtain good eggs it is necessary to adopt new methods. These are chiefly such as involve the use of the microscope.

Among the many diseases of silkworms, the principal ones are:

Pebrine, flacherie or flaccidity, gattine or macilenzia, calcino or muscardine, and grasserie.

PEBRINE.

This disease was first noticed in epidemic form in France in 1845. Since then it has appeared in Italy, Spain, Portugal, Turkey, Turkestan, the Caucasus, Kashmir, China, and Japan, threatening to destroy the silk industry.

Between 1833 and 1865 the annual crop of cocoons in France was reduced by pebrine from 57,200,000 pounds to 8,800,000 pounds. No remedy has been found for the disease, but the Pasteur microscopical selection of eggs, insuring the birth of healthy worms, is a sure preventive. The universal adoption of this method has made pebrine almost a thing of the past; and following Pasteur's line of research, means have now been discovered for avoiding every kind of silkworm disease.

Worms affected with pebrine develop slowly, irregularly, and very unequally. Black spots are the most marked outward characteristics of the disease; the internal signs are oval corpuscles only visible through the microscope.

Worms healthy born may contract pebrine during life, but this may not prevent their spinning, as the disease does not reach its climax before the chrysalid or moth stage, and in its incipency the worm is strong enough to spin, though the moth will produce diseased eggs. Hence the necessity of repeating the microscopical examination for each generation of worms.

Pebrine is not always visible, and when latent induces other diseases. When only one crop of cocoons is made annually, it is comparatively easy to resist pebrine, as the germ of it, outside of an egg, retains its vitality not longer than seven months. The disease takes thirty days to develop; therefore, if worms from pebrinized eggs can be made to spin within twenty-five days after hatching, they may yield a fair harvest of cocoons. In any case, however, it is only safe to use pure eggs, as pebrine, even in undeveloped stages, renders the worm more liable to contract all other diseases.

FLACHERIE, OR FLACCIDITY.

This is now the most dreaded disease among European silkworms. In general, worms are struck with it after their fourth molt, when they are mature, or even while spinning (fig. 13).

Without any apparent cause, they begin to languish, then remain completely still, and shortly die. They blacken after death (fig. 14), and give out a disagreeable odor. Often entire chambers perish in a day. Again, the progress of the disease may be slow, the worms even spinning their cocoons, but, dying in the chrysalid state, they putrefy and soil the cocoon, thus greatly diminishing the value of the harvest. Flacherie is but another name for indigestion. Pasteur and many



FIG. 13.—Worms affected with flacherie dying in the brush (after Pasteur).

other scientists assert that flacherie is due to ferments and vibrioni developing in the intestinal canal of the worm; other authorities maintain that the disease may exist independently of these. However, as these micro-organisms, in the majority of cases, play a prominent part in the development of flacherie, it is well to guard against them.

The principal causes of flacherie are: (1) Eggs being spoiled through careless preservation; (2) hereditary tendency; (3) overfeeding of worms; (4) wet, sweating, dewy, and fermented leaf; (5) leaf submerged in water or full of mud; leaf from a new plantation or from a shaded spot, coarse leaf, or change of leaf; (7) lack of ventilation; (8) excessive heat; (9) dust; (10) keeping worms too thick on trays; (11) accidental deaths of worms from injuries, these putrefying, and

the ferments thus created being communicated to other worms; (12) debility.



FIG. 14.—Worm which died of flacherie, putrefying after death. (Redrawn from Pasteur.)

If these causes are avoided, flacherie is not likely to invade a rearing. To prevent

contagion eggs should be dipped in a solution of sulphate of copper before being incubated; and in cleaning shelves and nets, wherever a dead worm is seen, powdered sulphate of lime or copper should be applied.

Unlike the corpuscles of pebrine, the microscopic organisms, which are probably the immediate cause of flacherie, remain alive from one year to another, and the dust of a rearing room may contain them in considerable quantities and become the means of infection. Hence, in cases of flacherie, immediately after the rearing, the walls, shelves, and all the implements should be washed in a solution of chloride of lime or some other germicide, and the room should be fumigated with sulphur.

GATTINE.

The external signs of gattine are indifference to food, torpor, dysentery, and emaciation. It attacks the worm in the first ages, and is especially manifested after a molt. Sometimes it is associated with flacherie, and, in its incipient stage, is confounded with this disease. Later the worm becomes extraordinarily emaciated and sufficiently transparent to be mistaken for a mature larva. The hooks of the prolegs are lengthened out and strongly attach the worm to whatever it touches. Meanwhile torpor creeps on and soon ends its life (fig. 15).

Worms having flacherie or gattine do not always die before mounting into the brush, and if the disease has not entirely invaded the organism they may even arrive at spinning. But instead of mounting with the promptness and rapidity of healthy worms, they stop hesitatingly at the base of the brush, then begin slowly to mount, stopping

on the first little twigs and distending themselves as though asleep, sometimes with the head turned towards the base. Again, especially in case of gattine, the worm wanders restlessly here and there, seeking as it were power to eject the silky matter, but too impotent to do more than throw out a scanty thread to weave a web or veil of a cocoon, in which it generally falls and dies.

Eggs free from disease and capable of resistance to disease are the prime requisite in guarding against flacherie and gattine.

The moment some deaths are noticed, proceed as follows: (1) Change beds immediately, briskly shaking the worms; (2) place the worms on disinfected shelves; (3) burn the diseased and suspected worms that do not mount on fresh beds; (4) if possible move the whole rearing to another room previously aired and disinfected, and also aired after disinfection; (5) do not feed during the three or four hours in which the change is being made; (6) keep up a little wood smoke in the room; (7) give a few scanty meals of light leaf; and (8) diminish the temperature a little.



FIG. 15.—Worm emaciated by gattine after the fourth molt. (Redrawn from Nenci.)

CALCINO, OR MUSCARDINE.

This disease, at first, has no visible appearance, but by degrees the vitality of the worm is impaired, and it eats and moves slowly. The body turns rose-colored or red, beginning with the stigmata, and then contracts and loses its elasticity, after which the worm stands still as though paralyzed, and finally dies 20 to 30 hours from the appearance of the first symptoms. After death the body dries up and is covered with a white efflorescence, causing it to look like a stick of white chalk (fig. 16); hence the name of the disease.



FIG. 16.—Calcinated worm.
(Redrawn from Verson
and Quajat.)

Calcino is caused by a mold or minute fungus. There are two varieties of this fungus: *Botrytis bassiana* and *B. tenella*. They both attack the worm in the same way. The spores of the mold by chance get on the body of the worm when it is in a molting condition, and there take root, penetrating below the skin. The thread-like mycelium ramifies until it fills the entire body. Later some of the branches fructify on the surface, and the fruit bursting envelops the worm with innumerable spores resembling a white powder.

Each spore is capable of settling on a molting worm and giving it calcino, hence the necessity of taking steps to avoid contagion. Calcino is more contagious than other silkworm diseases. Darkness, stagnant air, dirt, warmth, and moisture are the five things that favor mold, and calcino is a mold.

The chief cause of the disease is neglecting to change the beds and keeping litter in and around the room. When only one or two worms have died from calcino all the shelves should at once be cleaned and divested of dead worms. The floor should be washed with a solution of sulphate of copper (1 to 200 by weight), and a pound of sulphur should be burned, or a strong wood smoke created in the room, which should then be shut up five or six hours, after which the worms should be fed. Should any worms die the next day the beds should again be changed and an ounce of sulphur burned. The quantity of sulphur fumes that would kill rats, bats, and lizards and even human beings does no harm to silkworms. No hesitation, therefore, need be felt in fumigating the rearing room with sulphur; but eggs and thread nets must not be subjected to sulphur fumes. Silkworms affected with calcino die before the moth stage; therefore, it is impossible for the disease to be hereditary. But loose spores of the mold creating the disease may get on healthy eggs. These may be washed off by a good bath of fresh water. Some recommend a bath with a solution of sulphate of copper (one-half per cent of copper). In cases of calcino the room should be disinfected immediately after the cocoons are gathered and the paper and brush used should be burned.

As calcino is never due to infected eggs no attention need be paid to the presence of spores of the *Botrytis* in the microscopic examination to select eggs.

GRASSERIE.

Silkworms having this disease become restless, bloated, and yellow. If punctured they exude a purulent matter full of minute polyhedral, granular crystals.

Grasserie is neither hereditary nor contagious. Unlike pebrine, flacherie, and calcino, it is not caused by microbes capable of multiplying and creating plagues. Grasserie does little harm to silkworms in Europe, but in warm countries, as in Bengal, sometimes assumes an epidemic form.

Worms first fed on mature leaf, and afterward on young leaf, are apt to take grasserie. The propagation of large trees is the best means of checking the disease. The main cause of the sporadic appearance of grasserie is mismanagement of the worms at the molting periods. Feeding should not be stopped before all the worms have begun to molt, and should not be recommenced until all the worms are well out of the molt; otherwise they are likely to have grasserie. This disease often leads to flacherie, and when it occurs in an exaggerated form indicates latent pebrine.

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 165.

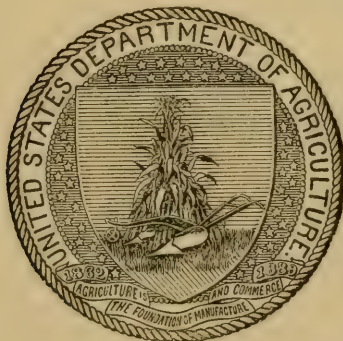
SILKWORM CULTURE.

BY

HENRIETTA AIKEN KELLY,

Special Agent in Silk Investigations, Division of Entomology.

[REVISED BY C. J. GILLISS.]



WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1903.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., March 5, 1903.

SIR: I transmit herewith an article on silkworm culture, prepared by Miss Henrietta Aiken Kelly, special agent in silk investigations of this Division, and recently published as Bulletin No. 39 (new series) of this Division, to which has been added a few paragraphs of information on the culture of the mulberry, condensed from Bulletin No. 34 of the Bureau of Plant Industry.

Miss Kelly has studied the culture of the mulberry silkworm as carried on in France and Italy for a number of years, has consulted the works of the best European authorities, and is therefore well qualified for this task. Although the silkworm industry has not attained much commercial importance in the United States, there is a popular demand for information on the subject which, it is believed, can be supplied to the best advantage by the republication of this matter in the popular Farmers' Bulletin series.

Respectfully,

L. O. HOWARD,
Entomologist.

Hon. JAMES WILSON,
Secretary of Agriculture.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,

JAMES WILSON,
Secretary of Agriculture.

December 17, 1908.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
WASHINGTON, D. C.

INFORMATION IN REGARD TO THE WORK IN SILK CULTURE.

The practical investigation of silk culture by the Department of Agriculture began as a result of an agitation on the subject dating from the Centennial Exposition of 1876, and was carried on by virtue of specific appropriation by Congress, continuing, practically, from 1881 to 1891 and again from 1892 to 1908. The experiments were conducted on an extensive scale, the work being placed under the supervision of the Bureau of Entomology.

The experience prior to 1886 had established the possibility of raising a most excellent quality of silkworm cocoons over nearly the whole country, but it had also seemed to demonstrate that the higher price of labor in the United States would preclude any profit from the industry. This was largely due to the fact that it was found impossible to convert the cocoons into raw silk, namely, to reel them, in this country in competition with the cheap labor in foreign silk-producing countries. Hence in America there could be no market for cocoons, and to sell them in France or other European countries meant a smaller compensation even than that received by the peasant silk raiser of Europe, on account of the long-distance freightage.

The work of the Department was, therefore, especially directed to efforts to remedy this state of affairs and to equalize by improvment of mulberry the difference in wages between our own and foreign countries, thus making it possible for the manufacturer to pay a better price for cocoons. Electric silk reels were set up and remained in operation for several years. Improvements in these reels were constantly being made in the direction of economy and efficiency, but it was definitely shown by 1880 that no silk reeler could afford to pay a price for cocoon which would induce even the poorest of our citizens (or even the foreign-producing members of his family) to undertake the rearing of an arduous labor of rearing worms. The sole remedy at that time seemed to be the levying of an import duty on reeled silk brought into the United States.

However, there seemed still a chance that even the very small compensation that might, under certain conditions, be gained from the sale of cocoon would prove attractive to the very poor, and between 1892 and 1898 appropriations for further investigations were made. During this period silkworm eggs, mulberry seedlings, and literature were widely distributed, and attempts were made by the Department to stimulate a market by procuring cocoons. At the close of the fiscal year 1908 Congress, deeming the efforts unavailing, ceased its appropriations. The result of the work has been to educate a large number of people in cocoon raising and many thousands of mulberry trees have been planted, thus, in part at least, insuring a supply should conditions alter and a future demand arise for home-grown cocoons.

In view of the above there can be no question but that disappointment will surely follow exaggerated ideas upon the subject of silk reeling for profit in the United States.

Should you desire to post yourself on the investigations conducted by this Department you will find the successive steps recorded in the following publications, which may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.:

Annual Reports of the Department of Agriculture for 1881-2, 1883, 1884, 1885, 1886, 1887, 1888, 1889, 1890, 1892, 1903, 1904, 1905, 1906, and 1907.

Should you wish merely to conduct some experiments, from a general interest in the subject and as a means of obtaining a knowledge of the habits and transformations of the insect, it is possible to obtain the eggs from Ambrogio Rodacelli & Figli, Varese, Italy. These should by all means be shipped in the month of November. The Department has no eggs for distribution.

L. O. HOWARD,
Chief of Bureau.

Approved: JAMES WILSON,
Secretary of Agriculture.

December 15, 1908.

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SILKWORM CULTURE.

The caterpillars of many moths and of a few butterflies produce silk, but certain of those belonging to the family Bombycidae, or true silk-spinners, particularly *Bombyx* (*Serica*) *mori*, or the mulberry silkworm, yield the most and the best silk. The races of *Bombyx mori* to-day are the result of domestication and artificial rearing, and the wild type is uncertain, though most authorities assign the foot of the Himalaya as the cradle of the mulberry silkworm. It has been industrially cultivated in China from time immemorial, and in Europe since the sixth century.

THE LIFE OF THE SILKWORM.

Like all insects of its class, before arriving at the perfect winged state, it exists (1) as a caterpillar or larva, and (2) in a chrysalis state.

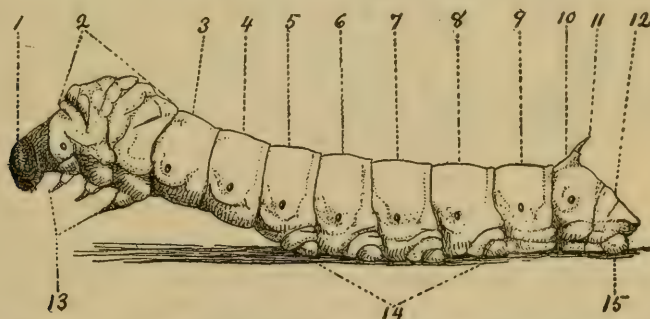


FIG. 1.—Adult silkworm: 1, head; 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, rings; 11, horn; 13, 3 pairs of articulated legs; 14, 4 pairs of abdominal or false legs; 15, a pair of false legs on the last ring.

THE LARVA, OR CATERPILLAR.

The larva (fig. 1) has a cylindrical body composed of 12 rings; each of the first three has a pair of jointed legs, and the sixth, seventh, eighth, ninth, and twelfth each bears a pair of false legs, destined later to disappear.

The black elliptical spots on the side are the orifices for breathing, and are called stigmata or spiracles.

The head is a small mass covered with a hard scale, and is provided with jaws that move laterally, like the wings of a folding door. The alimentary canal extends throughout the entire length of the body,

and on each side of it is placed a silk gland (fig. 2). These consist of two whitish or amber-colored cords, which after innumerable curves unite in the spinneret in the region of the mouth. There are also two glands, whose excretory canal opens in the spinneret, and covers the silk as it comes out with an impermeable varnish rendering it insoluble in acids and alkalies. This varnish is about a fifth of the weight of the thread.

Hatchings usually occur annually in the spring. Simple contact with the air causes the new-born insect immediately to acquire a volume larger than it had in the egg, and it quickly begins to gnaw the under surface and edges of the mulberry leaf. It eats day and night at all hours, except when asleep, and in about thirty days grows 14,000 times larger than it was at birth.

As the silkworm grows larger it becomes paler in color, because its dark chestnut brown hairs are scattered over a larger surface, thus showing more of the true color of the skin.

About five days from its birth the vitality of the larva decreases, and it eats scantily or not at all, and becomes thin and whitish in color. Then it moves around unquietly, and finding a convenient place attaches itself to it, holding on by its false feet. It thus remains motionless, with the front part of its body raised up, for a period of time varying according to temperature, and takes its first so-called "sleep," or molt, during which time the body undergoes extraordinary modifications. The skin is entirely shed, and all the tissues that can not keep up with the rapid growth of the insect are changed.

The scale which covers the snout is the first part of the case to fall, and a new case appears under the former one. The worm then pushes

itself forward through its first ring, sets at liberty the legs of the thorax, and by a wriggling movement comes out of its old sheath.

To facilitate this difficult change a liquid is secreted between the old skin and the one forming beneath it.

The life of the larva is usually divided into four ages, varying in length according to temperature, frequency of feeding, race, and the robustness of the worm. The following is about the average:

First age, from birth to first molt, five to six days.

Second age, from first to second molt, four days.

Third age, from second to third molt, four to five days.

Fourth age, from third to fourth molt, five to seven days.

Fifth age, from fourth molt to maturity, seven to twelve days.

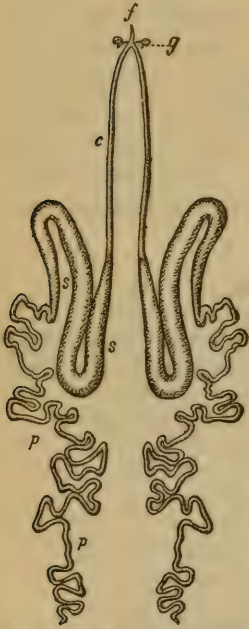


FIG. 2.—Silk glands in a mature worm: *p*, portion of glands which secrete the silky matter; *s*, reservoir; *c*, conducting canal; *f*, spinneret; *g*, accessory glands (redrawn from Verson and Quajet).

Some time after each molt, perhaps the time needed to regain lost strength and to solidify the newly-formed organs, the worm remains in a state of relative torpor. Not much practice is needed to recognize when it has come out of its "sleep." It moves its head and thorax, which are whitish, while the rest of the body is gray, and has completely lost the shining aspect which it had when the worm began to molt. When fairly through its first molt the larva begins again to eat, and its hunger does not cease until it is ready for a new molt.

Four molts having been made, the worm eats a prodigious quantity of leaf until it reaches its maximum growth, when its appetite diminishes and ceases altogether. It then stops moving and remains for some time in repose, **evacuating**, meanwhile, its digestive canal, thus losing up to 12 per cent of its weight. Its lean body is now white or yellow, according to the race, and semitransparent.

Very soon it begins to move about again, lifts up its head, which is longer and more pointed, and turns in every direction seeking to find a convenient angle, finding which, it throws out a silk thread from its spinneret. First a net is formed to hold the cocoon which is to be spun, then the regular spinning begins and the form of the cocoon is designed. For some time through the veil which very soon is to surround it, the diligent larva, with its back turned outward, may be seen completing its task. It is calculated that with its head alone the silkworm makes 69 movements every minute, describing arcs of circles, crossed in the form of the figure 8 (fig. 3, *a*).

Meanwhile the web grows closer and the veil thickens, and in about seventy-two hours the worm is completely shut up in its cocoon, which serves it as a protective covering.

THE CHRYSALIS.

In the cocoon the silkworm goes through the last phase of its larval life. After four or five days the skin breaks, and the insect which



FIG. 3.—The chrysalis: *a*, silkworm completing its cocoon; *b*, cocoon and chrysalis—cast-off skin of larva beneath; *c*, back view of chrysalis; *d*, side view of chrysalis. (Redrawn from Maillot.)

issues from this old covering is the chrysalis, whose weight is often only half that of the larva at its highest development (fig. 3).

The chrysalis seems to have neither head nor feet, is golden-colored at first, and then turns chestnut brown. The skin dries rapidly and forms a hard case, on which the lines of only the posterior rings are seen, the place of the first three rings being covered with the wing-cases.

The chrysalis state is in certain respects a sleep and in others a period of great activity, in which the entire being is transformed. Wings, antennæ, reproductive organs, and legs are all now developed. This state lasts from eighteen to twenty days, according to the temperature. When the metamorphosis is complete, the sheath breaks in the region of the head and the moth or perfect insect issues.

THE MOTH.

The larva in spinning the cocoon leaves one end less dense, so that the threads open freely to permit the egress of the moth. By the aid of an alkaline fluid the moth softens and parts the threads and liberates itself.

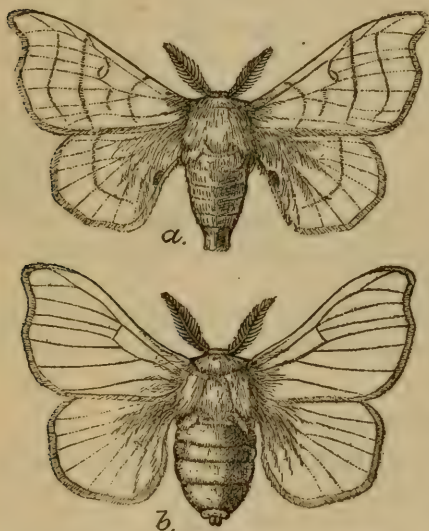


FIG. 4.—The moth: *a*, the male; *b*, the female.

The moth (fig. 4) comes out of the cocoon, as the larva out of the egg, in the early morning hours. It has a distinct head, thorax, and abdomen, four wings, two comb-shaped antennæ, three pairs of legs, and a pair of compound eyes.

Shortly after emerging, the moth deposits a liquid substance, generally white, sometimes colorless and sometimes reddish, and then the union occurs, lasting several hours, after which the eggs are laid either immediately or in the course of four or five hours.

A gelatinous substance supplied by two glands near the extremity of the oviduct covers the eggs as they come out, and causes them to adhere to the substance on which they are laid.

The laying, consisting of 300 to 700 eggs, is generally completed in three days, 70 to 80 per cent being deposited the first day, 20 to 30 per cent the second day, and a few the third day. The mother moth dies six to twelve days later, her death being usually preceded by that of the male. Death occurs more or less speedily, according to the robustness of the moth, the temperature, and the tranquillity in which it has been left.

Thus in about sixty-five days the silkworm has completed its cycle of existence, its three periods being thirty to forty days in a larval

state, fifteen to twenty days as a chrysalis, and eight to twenty days as a moth or perfect insect.

The rapid development of the silkworm and its marvelous transformations indicate extraordinary power and very active functions. Its respiration is almost equal to that of the frog and of certain large birds, and it must be always surrounded by plenty of pure air.

THE FOOD OF THE SILKWORM.

The leaf of the white mulberry is the natural and the best food for the silkworm. There are many varieties of the white mulberry—some much better adapted than others to commercial silk culture, and some better suited to certain localities.

CULTURE OF THE MULBERRY.

As the securing of a food supply is a necessary condition to silkworm culture, some information on the culture of the mulberry, condensed from a bulletin of the Bureau of Plant Industry,^a is inserted:

Of the mulberry there are many so-called species and a great many varieties, but there are only one or two species and a few varieties which are of importance in silkworm propagation. Chief among these for producing silkworm food is the white mulberry, *Morus alba*. This is thought by some to be a native of China. It is hardy over a large area of the United States.

Most of the silkworms reared in China are said to be fed upon *Morus multicaulis*. This mulberry was largely planted in the United States many years ago. Few, if any, of the original trees remain, but specimens which are thought to be wild seedlings of these are very plentiful in the Southern States. These trees are thoroughly acclimated and free from disease. It is therefore probable that there is now in the United States an abundant supply of material for propagating purposes, at least. The white mulberry, under good cultivation, is a low-growing tree, seldom attaining a greater height than 25 or 30 feet. It will reach this height in a comparatively few years after planting. In the vicinity of Washington the trees flower about the middle of May and ripen their fruit during June.

The mulberry may be propagated by means of seeds, cuttings, layering, grafting, and budding. Seeds and cuttings are, however, the least expensive and troublesome, and the most satisfactory means of propagation.

Propagation by Means of Seeds.—This is the most convenient and rapid method of propagation. To remove the seeds from the berries, place them in a large bucket or a tub and squeeze them with the hands until they form a jelly-like mass. Add water and stir well to allow the seeds to sink to the bottom. The water and pulp can then be poured off, and the seeds can be dried by exposure to the air.

The seeds may be planted at once, or they may be kept over winter and planted in the spring. Beds about 5 feet wide should be thoroughly prepared. The seed should be sown broadcast, not too thick, as crowding makes weak plants. Press the seeds in with the back of a spade and cover lightly with fine soil. For protection from the heat of the sun, over the beds should be placed lattice-work screens made of lath, and over these canvas should be spread until the plants show above the ground. After that the canvas is unnecessary except in the hottest part of the day. With spring-sown seeds the lath screens without canvas will be sufficient.

^aBul. No. 34, Bureau of Plant Industry, U. S. Department of Agriculture. By George W. Oliver.

Seedlings vary considerably from the parent tree, and many of the seedlings grown will be found to have leaves of undesirable quality. Hence careful selection should be practiced and many of the seedlings must be rejected.

The Use of Cuttings.—For propagation by means of cuttings in the summer time, selected seedlings which have made considerable growth may be used. Two or three leaves clipped to half their length should be retained on the cutting (fig. 5, *a*.) The cuttings should be set sloping in beds of moist sand in a cool propagating house, or, if such is not available, in a cold frame with northern exposure; if in the shade of trees, so much the better. The sash should be kept closed to conserve the moisture of the atmosphere until the cuttings have taken root. When considerable root

growth has been made they should be transferred to beds in the open, being placed 6 inches apart each way and well watered until established.

The supply of winter cuttings should come from dormant wood taken from the trees just after the leaves have fallen. The cuttings (fig. 5, *b*) should not be less than one-fourth inch in diameter and should be about 10 inches in length, the top cut being made about a half inch above a bud. The cuttings should be tied in bundles of 50, and these may be buried in moderately moist sand or ashes until spring, when they can be put out in rows in well-prepared soil. These nursery rows should be well cultivated and kept clear of weeds.

Another method of propagation from cuttings, and a very successful one, consists in selecting medium-sized shoots about the beginning of November. These, before being made into cuttings, are sorted into bundles of different lengths, tied, and heeled in ashes or sand, or in a mixture of both, and protected by a frame having a northern exposure. During the winter they are taken out and cut



Fig. 5.—Mulberry cuttings: *a*, a summer cutting; *b*, *b*, winter cuttings.

into lengths of about 5 inches. These are tied in bundles and buried in moist sand or moss. In early spring they are untied and put quite thickly in a propagating bed having a mild bottom heat, where they will root rapidly. When such a bed is lacking, wooden flats about 4 inches deep may be used, but they must have the protection of a frame covered with sash. If a little loamy soil is placed in the bottom of the flats the cuttings will remain in good condition for a considerable time after rooting and until a favorable opportunity arrives for planting them out in nursery rows.

Planting.—The mulberry grows well in a great variety of well-drained soils. The young trees should be transferred from the nursery to their permanent places either

in the fall or in the spring. If in the fall, the transplanting should be done when the leaves have matured or fallen. In the spring transplanting may take place as soon as the ground is in good workable condition. The ground should be deeply plowed and thoroughly harrowed. If the ground is hard and the soil poor, large holes should be dug and filled with good soil as the trees are planted. In transplanting the roots should never be allowed to get dry. When taken up they may be immediately dipped in a mixture of soil and water and then kept covered until planted.

The distance between the trees should not be less than 10 feet each way. If the grove is to be large, wider spaces should be left at intervals, so that wagons may be driven through.

Pruning.—Pruning is best done in the fall or winter. The central part of the tree should be kept open to admit light and air. The low, spreading form of tree is much the best, and this form is secured by systematic pruning, which is begun by cutting the young tree back one-half in the fall after it is first planted out. Afterwards three or more strong shoots should be selected to form the main branches, and, if necessary, these may be prevented from growing upright by means of sticks fastened between them in such a way as to force them to spread apart.

In gathering the leaves always allow enough to remain on the tree to insure its perfect health. If some of the trees show signs of failing vigor as a result of excessive leaf gathering, it is advisable to allow them to grow for a season without picking, and by early pruning out of unnecessary growth permit those growths which are desirable to become ripened.

Restricting the height of the trunk of the mulberry to 5 or 6 feet makes it possible for old women and children to gather leaf, thus diminishing the cost of labor one-half, a most important point in commercial silk culture.

It is also important to cultivate trees that bear little or no fruit, for the production of fruit not only consumes part of the strength of the tree, but much labor is involved in being compelled to divest the branches of fruit before they can be used as food for silkworms.

The stump mulberry, or that growing low like a shrub, the hedge mulberry, and that which grows along walls vegetate much earlier than the medium and high trunk trees. Silkworm rearers should always have a ready supply of leaf for the first ages of the worm, and especially is this necessary if early cultures are desired with a view to escaping the heated days of May and June.

AMOUNT OF LEAF AND PREPARATION.

The race, the size of the worms, the variety and age of the mulberry, the nutritive quality of the leaf, the year, the season, and the climate make the requisite quantity of leaf very variable. The following is given as a basis of calculation, all circumstances being considered, and the leaves not being cleaned: For the larvæ hatching from 1 ounce of eggs, during the first age, 11 pounds of leaves; during the second age, 26 to 33 pounds; during the third age, 88 to 145 pounds; during the fourth age, 264 to 352 pounds; during the fifth age, 1,540 to 1,760 pounds; or about 2,200 pounds in all, of which one-half is consumed in the last six or seven days of the fifth age.

The age of the leaf should be relative to that of the worm. Young worms fed on old leaf, or old worms fed on young leaf, are apt to become diseased, and even though they may not die, will scarcely molt or will spin indifferently. A change of leaf, too, should, if possible, be avoided, or made gradually. Fresh leaf only should be used,

and never when wet with dew or heated, or before it has in a measure acquired the temperature of the room in which the worms are being reared. It should be gathered early in the morning or in the evening and should not be bruised or torn, nor should the baskets or aprons used to carry it be the same which are used to remove litter. To avoid fermentation the leaves must be spread out in a cellar or cool, darkened room. Cut up only a limited quantity of leaf at a time and cover with a damp cloth to keep fresh, but never submerge the leaf in water, as this is apt to occasion *flacherie*, a very destructive disease. From the fourth age on

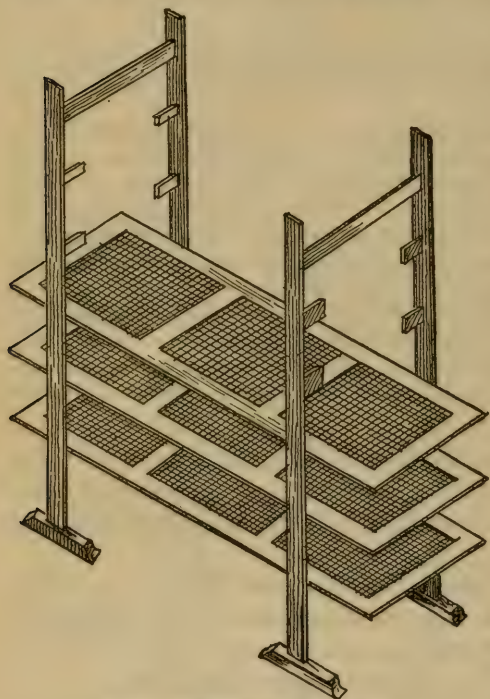


FIG. 6.—Light movable shelves.

there should always be a day's supply ahead, so that in case of rain the worms will not have to fast.

In gathering leaf, always strip the branches from base to top, so as not to tear the bark and injure the new buds. The sacks for holding the leaves should have a hoop around the opening and a hook to suspend them to the branches.

IMPLEMENTS NECESSARY TO SILKWORM CULTURE.

Commercial silk culture requires a smaller outlay of capital than almost any other industry. The net gain the first year may pay for an outfit which will last for many years. The following articles are indispensable:

- (1) Some very light movable shelves, open to air, for the first ages; and, for the following ages, latticed shelves about $3\frac{1}{2}$ feet wide, and stands to support them.
- (2) Unsized ordinary wrapping paper or newspapers to cover the shelves.
- (3) A small ladder, if necessary, to reach high shelves.
- (4) Small trays to remove worms.

- (5) Knives to cut leaves and baskets to distribute them.
- (6) Coarse tulle and nets or perforated paper for changing beds and equalizing the worms.
- (7) A supply of brush, straw, or shavings to construct the spinning place.
- (8) A thermometer.

Wire, twine, laths, or canes are suitable for the lattice work of the shelves. Make the space between the shelves about 14 inches. If



FIG. 7.—The rearing room (after Gobin).

possible, do not arrange the shelves along the wall, and allow a good passage between the tiers of shelves (figs. 6 and 7).

SILKWORM EGGS: HOW TO WINTER AND HATCH THEM.

There are two kinds of silkworm culture: One for production and one for reproduction. The object in the first case is to get the greatest yield of cocoons, and with a little training, may be carried on by anyone of ordinary intelligence.

The object in culture for reproduction is to secure eggs free from hereditary taint of disease, and experts only can be depended on to conduct it. Besides a careful physiological examination throughout the rearing, the body of the mother moth is microscopically tested after death, and her eggs are not retained if signs of disease are discovered. In this way the birth of healthy worms is insured. Pasteur first applied this method of selecting silkworm eggs, and thus checked the plague (pebrine) which was rapidly destroying silkworm culture in Europe.

Formerly, through an indiscriminate use of eggs, disease invaded the rearings to such a degree that from 65 to 90 pounds of cocoons was considered a good yield per ounce of eggs. At the present low price of silk such cultures are no longer remunerative, and industrial silk culture now demands the exclusive use of scientifically tested eggs.

The grainage, or preparation of eggs for market, constitutes a special department of silk culture. In Italy there are over 400 establishments which supply eggs to raise the annual silk crop. The poorest peasant, though well skilled in the art of rearing silkworms, would not risk a rearing with eggs which have not been selected and preserved by experts.

The eggs of crossed races are best for culture with a view to production of silk, and here, as much as in the examinations which have been referred to, the knowledge of experts is needed.

The life of the egg, in those races which have but one generation each year, has three phases, the first lasting about three months, full of activity; the second lasting from about October to the middle of February, one of inactivity, in which there are no signs of life; the third from the middle of February to the moment of hatching, in which the vital activity recommences, and the germ begins to organize as soon as the temperature rises a little above 50° F. The measure of the activity of the egg, in this stage, is the measure of its danger, for any sudden change of temperature would injure or destroy the delicate embryo, or cause the larva to be born before its food was ready. To guard against such accidents, eggs must be wintered in a high region or in a refrigerator at a uniform temperature of about 35° F., from December 15, until the mulberry begins to bud or until hatchings are desired. There should always be good ventilation, the air should not be moist, and great care must be taken to keep the eggs out of the reach of mice and insects.

Natural hatchings are almost always irregular, extending over eight or ten days, thus multiplying the divisions and rendering the rearing difficult and costly; hence, the necessity for artificial incubation.

Eighteen days before the time decided on for the hatching, spread out the eggs in thin layers in the incubating room or incubator. The temperature should be 55° F.

From the fourth day on, gradually increase the temperature two degrees in twenty-four hours until 73° F. is reached, when, at this uniform temperature, hatchings will occur in ten days on an average. This period, however, varies from eight to fifteen days, according to race, the cold supported during the winter, the first grade of heat, and the highest during the incubation, and the number of days taken to pass through these two grades of heat; and also according to the humidity. To obtain a good and complete hatching, a slight humidity

is necessary, especially during the last four or five days. To secure this keep an open vessel of water near the fire, or sprinkle the floor with water occasionally.

The temperature may be raised during the hatching to 75° F., but sudden changes of heat must be avoided, and, unless the newborn worms can be kept in the same temperature, it is dangerous to have the maximum temperature of the incubator so high.

It is better for the period of incubation to be protracted than suddenly shortened. Holding the eggs at a certain temperature, or slowly lowering the temperature a little does no harm. When the season is not propitious, the hatching may in this way be retarded.

An incubating room is preferable, because it also serves for the first two stages of the worms, but in small rearings an incubator is more economical, both with regard to service and to fuel.

For a large quantity of eggs (5 to 10 ounces) a small incubator, which is very much used in chemical laboratories to dry substances, is recommended. Any ordinary tinsmith can make it. It consists of a double case, cubical in form, with a zinc bottom. The space between the outer and inner walls is filled with water. The front face of the cube is furnished with a glass, so that the temperature within, indicated by the thermometer hanging on the glass, may be seen without the necessity of opening the incubator. There are two openings below on opposite sides to allow the cold air to come in, and an opening in the center of the top to permit the outward flow of the

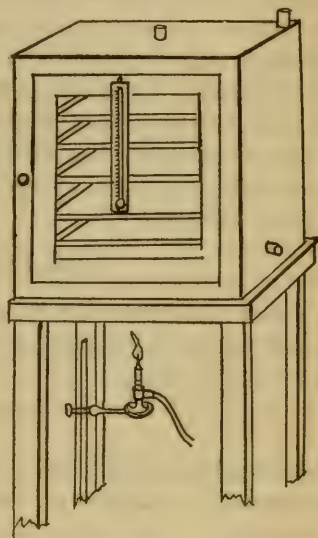


FIG. 8.—Hot water incubator. (Redrawn from Verson and Quajat.)

heated air. Having filled the space between the walls with water through the pipe, the incubator is placed on a support and heated by means of a gas or oil lamp to the desired degree, and, by raising or lowering the flame, a constant or progressive temperature can be maintained (fig. 8). A self-regulating incubator, such as is used to hatch chickens, would be more convenient, but would cost more.

The whitening of the eggs denotes the near approach of the hatching. Double pieces of tulle or sheets of perforated paper sprinkled over with finely cut-up white mulberry leaves should then be lightly placed over the eggs to allow the outward passage of the worms as soon as hatched. The object in employing two pieces of tulle or paper is to prevent the unhatched eggs which cling to the sheet from being removed with the newborn worms. This process must be

repeated daily during the hatching, the second sheet always being renewed.

The duration of the hatching varies from three to five days, the eggs hatching about as follows: During the first day, 5 per cent; during the second, 33 per cent; during the third, 50 per cent; during the fourth, 5 per cent; during the fifth, 7 per cent.

Twenty-five grams of eggs will give about 17 grams of worms. In small rearings most cultivators raise only the worms that are hatched on the second and third days, to avoid the necessity of forming too many classes. The worms must be classed according to the date of birth, and the insignificant number hatched on the first and last days scarcely compensate for the trouble of rearing them. Different races must also be reared separately.

Where several in one neighborhood are engaged in silk culture it greatly reduces the cost to have all the eggs hatched in one incubator. The person best acquainted with silk culture can undertake the incubation, and distribute the young worms on the second or third days to those who are to rear them. This is the plan adopted among the Italian peasantry, the wife of the supervising farmer hatching the eggs for whole villages.

THE REARING OF SILKWORMS.

Before entering into the details of a rearing some general directions must be given concerning the rearing room—the heating, ventilation, and disinfection.

GENERAL DIRECTIONS.

The place chosen for a rearing should be relatively high, and not exposed to malaria or bad odors, and mulberry trees should grow around it. Any room that can be properly heated and ventilated will answer the purpose. An open fireplace is the best means of heating, but is expensive, as much of the heat is lost. Hot-water pipes, such as are used to heat a greenhouse, are good for a building specially built for silkworm rearing. Iron stoves should not be used, unless placed in an adjoining room with communicating pipes. Never employ charcoal as fuel.

Ventilation.—The domesticated worm should be surrounded continually by pure air. The amount of carbonic-acid gas given out by the worms and their attendants is very considerable; besides this, a quantity of deleterious gas is generated by the litter of the beds, and the lights and fires consume a great deal of oxygen. Myriads of spores and germs of organic life float in the air of the rearing room, and their influence paralyzes the vital energy of the skin and of the organs of respiration, on whose normal functions the robustness of the worm so much depends. Hence, it is evident that the quantity of

vitiated air which should be expelled from the room requires the introduction of a large quantity of fresh air. For this, a double system of ventilation is necessary, which may be obtained by double openings in the windows, to allow the heated bad air to pass out above and the cool fresh air to come in below. To renew the air in every part of the room, and to avoid a single and often violent current, there should be more than one window. An open fireplace is the best means of ventilation. When the difference between the external and internal air is slight, or there is no difference at all, artificial means must be used to create a current. Light and frequent fires, or a burning lamp in the fireplace, or a revolving fan, may be used to prevent stagnation of the air.

Disinfection.—Eight or ten days before introducing the worms into their quarters all the shelves and implements should be washed in a solution of chloride of lime (11 pounds of chloride of lime to 88 quarts of water), or in a solution of sulphate of copper (1 to 100 by weight).

When everything is in order—tools, perforated paper, material for the worms to spin their cocoons on, etc., each in its own room—close the doors and windows as tightly as possible and fumigate the rooms with sulphur (11 pounds of sulphur to every 100 cubic yards of space). To fumigate properly, powder the sulphur and place it in an earthen or metallic vessel over a slow fire. The sulphur will gradually melt and take fire. Place it immediately in the rearing room and leave it, with the doors and windows completely shut, for twenty-four hours.

Nets should not be exposed to sulphur fumes, for this would soon rot them, but should be washed in a solution of sulphate of copper, and immediately afterwards in plain water.

Twenty-four hours after the fumigation the floors should be washed with a solution of chloride of lime or sulphate of copper, and the walls should be whitewashed with lime.

When dead worms are seen on the shelves, change the beds and create in the rearing room sulphurous gas by burning a pound of sulphur during six hours, or make a strong wood smoke, which is a good disinfectant and will not harm the worms.

Precaution having been taken to destroy germs of disease in the rearing room, the new-born worms may now be safely installed there.

Space Required.—The worms from 1 ounce of eggs should cover at birth 1 square yard. Doubling this space on the fourth day, they would require 2 square yards, and at their change of beds after molting, 4 square yards. By the spacing of the third day of the second age, and the doubling of beds preceding the second molt, they will need for the second age 8 square yards. For the third age 16 square yards will be required; for the fourth age 32 square yards; and for the fifth age 60 square yards. The more space that is accorded to the

worms in their first ages, the more robust they will be; and if the space can be tripled instead of doubled during the fourth age, and for the fifth age be 70, 80 or 90 instead of 60 square yards, the harvest of cocoons can be raised from 60 kilograms to 70, 80, or 90 kilograms per ounce of eggs, the quality of silk also being superior.

Temperature.—The silkworm is not a tropical insect, and attains its best development between the temperatures of 68° and 77° F. It is safe to adopt the mean between these two temperatures for the general rearing. Each cultivator, however, may suit his convenience, remembering that to fall below or to exceed the mentioned limits of heat is detrimental to the worm, and will affect the quantity and the quality of its spinning.

From the second age the temperature should be from 70° to 72° F. and should be kept as uniform as possible to the end of the rearing. The time which elapses between one change and the following one may be much shortened by raising the temperature and feeding oftener. Such hasty rearings may be made in twenty-two to twenty-four days. They are, however, to be condemned, as contrary to the nature of the silkworm. Meals following each other too closely can not be properly digested, and are likely to cause disease. Besides, hasty rearings require more labor, and the service must be kept up night and day. As there is danger in too high a temperature, so there is danger in one that is too low (64° to 68° F.). A rearing that is too prolonged, lasting over thirty-two days, is to be avoided to escape the heat of June, under which the beds are more likely to ferment, causing disease; the worms have less appetite and leave more leaf from one meal to another; the changes are slower and less likely to occur instantaneously; and there is more risk of muscardine or calcino, a disease due to a mold.

Both hasty and tardy rearings are, therefore, to be proscribed, and those conducted in twenty-eight to thirty-two days alone are recommended. This lapse of time permits the leaves of the mulberry to acquire maturity, and the growth of the worm should be relative to that of the leaf on which it feeds.

THE FIRST AGE.

Hatchings usually occur early in the morning. The worms which have crawled up through the holes of the tulle or paper to get food, should not be removed before 10 a. m. to the latticed shelves covered with paper to receive them. Each shelf must be marked with the date of the birth of the worms put upon it, and care must be taken to place on the same shelf only worms born on the same day, as a remunerative rearing demands that such alone be raised together.

Should the hatching occur at 68° to 70° F., keep this temperature during the first ages, and feed eight times during twenty-four hours; if

the temperature at birth is 75° to 77° ., slowly diminish the temperature one or two degrees, and feed ten times in twenty-four hours. The appetite of the worm increases or diminishes with the heat. The second day, in case of the worms hatched at the maximum, adjust the temperature to the degree proposed to conduct the rearing. In feeding sprinkle finely cut up tender leaves frequently over the worms, and toward the fourth day begin to regulate the number of meals so that it will range from four to eight, according to the temperature. Before cutting the leaf remove the stems. Distribute the leaf uniformly and equally on the shelves, in order to prevent the worms from crowding more on one side than another, and in order that they may be equally nourished and make their changes simultaneously. Cut only a small quantity of fresh leaf at a time, and keep the rest in jars or baskets covered with a damp cloth. Never submerge the leaves in water. For the first two or three ages, the white ungrafted mulberry is recommended, it being lighter and more digestible for delicate worms.

It is well during the feeding to open the door and windows to insure a good supply of fresh air. After feeding, close the door and windows, unless the day is warm, when they may be permanently left open, protected by curtains through which the air passes freely. The worms should never be exposed to direct sunlight or to a strong current of air, and during a thunderstorm the windows and doors should be closed.

Worms of the same age and development should be classed together. To obtain this equalization, do not feed newborn worms until all that have been hatched on one day have been removed to shelves, then give a general meal. If at the end of two or three days it is noticed that on certain shelves there are smaller worms than on others, in order to allow the less developed worms to catch up with the more advanced ones, place the former nearer the fire or on the highest shelves, where the air is warmer, and give them one or two more feeds than the larger worms. For this reason it is well to have light movable shelves.

Many cultivators of silkworms do not change the beds during the first age, and it is not absolutely necessary, if the leaf has been well cleaned of stems and very finely cut up, and, above all, if the air is dry. Change of bed, however, must be made if the litter is damp, and the weather rainy, for the worms are going to molt in two or three days, and this crisis should not occur in unhealthy conditions. It is always more prudent to change beds on the fourth day, and is, therefore, advised. The space occupied by the worms must be doubled when the change of beds is made.

The bed on which the leaf and excrement accumulate is, perhaps, the greatest source of danger to the worms. When there is not a free circulation of air, gases are developed which almost always cause fermentation, paving the way for future disease. Hence the necessity for frequent change of beds. This is made in various ways. The

practice of doing this by hand is to be condemned because it consumes too much time and is apt to injure the worms. Thread nets (fig. 9) and perforated paper are the best means to employ. They save two-thirds of the hand labor, and thus allow beds to be oftener renewed, which is a most important consideration. In the first age tulle or mosquito net may be employed instead of nets or paper.

The manner of proceeding is as follows: Place the last meal at night on the nets and extend them over the worms. By morning the worms will have mounted above the opening in search of fresh leaf. Then lift up the nets, beginning at the top shelf, and place them on clean shelves. Carefully detach from the nets any portion of the old bed, and, if the worms are not molting, gather up the few worms that have remained behind, and tenderly place them with the others. The change of beds is thus rapidly effected with the least labor.

It is very important that the tension of the net be such as to prevent the worms from being crowded together in the middle.

Perforated paper (fig. 10) is another means often used to effect change of beds; but it does not allow the worms to mount with the same facility. It is also apt to break when the worms become heavy, and in many cases it has to be renewed annually, so, in the end it is no cheaper than nets.

In changing beds, do not feed the worms that are first taken up until all from the old bed

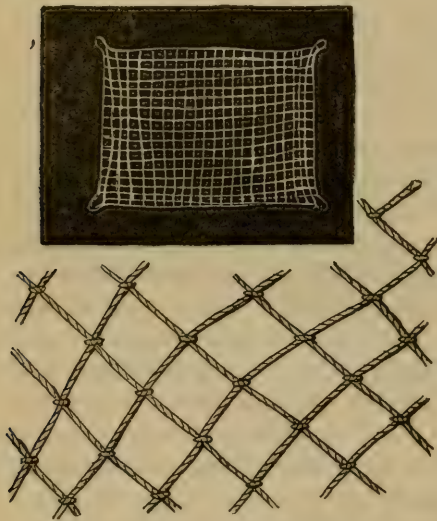


FIG. 9.—Net used in changing beds.

have been removed; then give a general meal, for all the worms born on the same day and forming one class should have the same number of meals to preserve their equality of growth, which is necessary for a successful rearing.

Having adopted hours for feeding, these should be adhered to throughout the rearing. When four meals are given, the best hours are 5 to 6 a. m., 10 to noon, 3 to 6 p. m., and 9 to 11 p. m.

Toward the sixth day worms begin to eat less. This is a sign that they are going to molt. Then another change of beds and doubling of space are necessary.

The molt or change of the worm is easily recognized by a swelling of the head, whitening of the skin, transparency of the body, and a fixed position.

To change the beds, proceed as before, only leave undisturbed on the old beds the worms that are molting. When all the tardy worms have been taken up and placed on shelves, give them frequent sprinklings of finely cut up leaf to enable them to catch up with the worms already molting. Diminish the feeding as the backward worms begin to molt, and cease feeding entirely as soon as a single worm comes out of the molt. Then wait twenty-four hours so that the worms may be well over the change before giving a general feed. In this way the equality of development necessary for a methodical and successful rearing is maintained. A fast of twenty-four hours will not hurt the advanced worms, while the extra feeding given to the backward ones may enable them to become equal to the former.

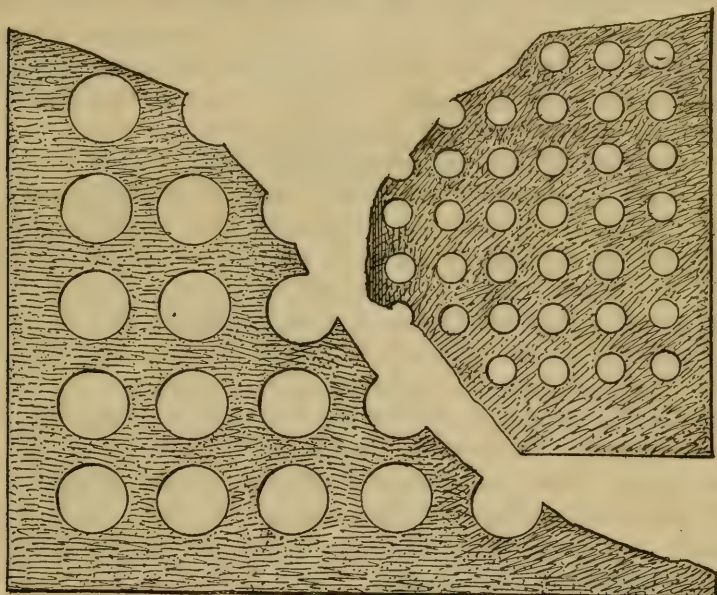


FIG. 10.—Perforated paper used in changing beds in the second and third ages.

The beds or the worms on the old litter may be changed when the general meal is given.

Many cultivators do not change the beds and double the space until after the first molt, allowing all the worms to change in the same bed. In this case, owing to the distribution of leaf for one or two days after the molting has begun, the molting worms are covered by a more or less thick coat of litter, and exposed to emanations of bad gases in a critical period of life, which is likely to cause disease. Besides, in the first age, the worms are so small that they are likely to be lost in the litter, or to perish from suffocation. Hence, it is healthier to change beds and double the space before the molt.

THE SECOND AGE.

The coming out of the molt is announced by the appearance of a small triangular-shaped livid spot on the worm's head, and the changed skin is grayish in color. The worm takes several hours to recover from a change; then it begins to search for food, which, however, as before stated, must not be given before all the worms have recovered from the molt. Then a slight meal is given by means of perforated paper or nets. The worms crawl up promptly and can be easily gathered up and placed on fresh shelves.

If the two sets of worms recover from their molt at the same time, they may be classed together; if there is a difference of a day, it will be necessary to keep them separate throughout the rest of the rearing, for the equality of age has disappeared, and, if they are put together, the second change will not occur simultaneously for all the worms, but will extend over several days, and occasion the greatest trouble to reestablish the equality of size necessary for the best results.

In case no worms have had change of bed before the molt, do not recommence feeding until the greater part of the worms are awake. Do not fear that they will suffer from hunger. Then form a new division of those still molting. It is frequently better to have two divisions, but if, to simplify the work, but one is desired, by putting the backward worms on the highest shelves, and feeding them oftener than the advanced set, an equality may be reestablished.

Three days after the first molt the beds must be renewed, and at the same time more space must be allowed the worms.

The second age is the shortest, being less by two or three days than any of the others. Toward the fifth day of this age the worms begin to molt again. Then act as before—that is, by aid of nets or perforated paper, remove the backward worms, in order to place them elsewhere, and try by more heat and abundant food to make them catch up with the forward worms.

THE THIRD AGE.

When the worms are over their second molt they cease to be gray, and take the characteristic color of their race. If they are too long in molting it is because the temperature is too low; that is, below 68° F. Increasing the heat a few degrees will excite the worms and enable them to complete their change. After this the temperature adopted for the rearing must gradually be resumed.

The worms double their size in their third age; consequently the space allotted to them must be doubled; that is, they must have 16 square yards instead of 8 square yards, as in the second age.

From the second to the third molt the same care is to be given as has been prescribed for the first two ages, except that, if a small incubating room has been used instead of an incubator, the worms must

now be transferred to a larger room to complete the rearing. Care must be taken to heat this room the day before to 80° F., and the next day lower the heat to the degree adopted for the rearing. Feed six times daily either with whole leaves or leaves which are coarsely cut up. For this as well as all the other ages the best rule to follow in feeding is to give only a light sprinkling of leaf at the beginning and end of each age, gradually increasing the ration up to the middle of each age, and then diminishing to the time of a molt. The appetite of the worm will serve as a guide. Give more or less leaf according as the preceding meal has been more or less eaten. In this way leaf will not be wasted and a large quantity of litter will not accumulate under the worms, to their detriment.

Toward the sixth or seventh day of the third age, according to the temperature, the worms begin to be languid and lose appetite, as before, and are ready to make a third change. This is the most difficult of all and the one in which they seem to suffer the most. It is also the period when diseases due to bad eggs or to a poor incubation are developed. Excepting accidental diseases, a good result may generally be predicted if the third change is safely passed. With these facts in view, from the beginning of the third age keep the worms sparse on the shelves and see that the beds are dry and changed with scrupulous care, the litter being far removed from the rearing room. Avoid feeding with wet leaf, and to favor the molting raise the temperature a degree. It will be noticed that the head and body of the worm are more swollen than in other molts. It is this superabundance of liquid that renders this molt so critical and necessitates a drier atmosphere and a bed which is very dry and not apt to ferment.

The worms increase three times in volume after the third molt, and must have space accordingly. They must be separated into three divisions in the following manner: Instead of waiting, as in the first two changes, until half of the worms have begun to molt, let down the nets, or otherwise prepare for the removal of the backward worms when one-third or even less of the worms show signs of molting. About two-thirds will then crawl up on the fresh leaves, and must be placed on a shelf where, after one or two meals, they proceed to molt, being again divided after the first or second distribution of leaves, according to the rapidity of the molting.

If only a few worms mount when the first division is made, the operation was delayed too long, and it is unnecessary to divide those first taken up; but after the change the division of those left on the old bed can be made. To allow the worms to spread out, each division should occupy but one-third of the shelf on which it is placed.

THE FOURTH AGE.

When all the worms have molted the third time a change of beds must be made as in preceding ages. Do not be in haste to change.

Wait a few hours to permit the worms to recover their strength a little. The recommendation to feed lightly at first applies especially to the beginning of the fourth age.

If the outside temperature is normal, fires need not be kept up, and the doors and windows may be left open, guarded by light curtains. In this age the worms eat enormously and more help will be required to gather and distribute leaf. Small branches of leaf may now be given in place of whole leaves, and the number of meals may be reduced to four, if the temperature is 68° to 70° F., at which temperature the age will last nine days. If it is desired to reduce this age to seven or eight days, raise the heat to 72° F., and give five or six meals daily. Should change of weather retard the growth of the mulberry trees, and temporarily cut off the supply of leaf, adapt the rearing to such a contingency by lowering the temperature slowly to 66° or 68° F., and giving only three or even two meals daily. Then, when leaf is obtained, gradually raise the temperature to the degree adopted for the rearing.

During the fourth age four changes of beds are made, including the one which follows the third molt. A single division of the worms is sufficient, which will be the last, and particular care must be taken to divide the worms into two equal parts. For this, spread the nets or perforated paper over the worms when half are molting and proceed as before.

THE FIFTH AGE.

Do not be in haste to change beds as soon as the worms have molted. This precaution is necessary to allow the new organs to acquire consistency, and to prevent worms from being lost in the litter. Consequently, wait several hours, and change beds after the second meal, the first being only a slight sprinkling of leaves. Worms are not strong enough immediately after a change to digest a heavy meal.

The space during this age should not be limited. See that between two worms another could be easily placed. Experience has proved that the harvest of cocoons is often in proportion to the space accorded to the worms during this age.

Feed from four to six times daily, according to the temperature, and spread the branches or leaves out regularly, not to form a mass. For a simultaneous mounting into the brush all the worms should eat an equal quantity of food.

As ripe berries are very indigestible, and also cause beds to ferment, care must be taken to shake the trees well before gathering the leaves, and whatever ripe fruit remains must be taken off before feeding.

If possible, change beds daily, especially if more than five meals are given, or if the weather is very warm and damp and there are signs of disease.

The first five days after the change the worms grow enormously, and it is very difficult to satisfy their appetite. At the end of this

time the body suddenly diminishes in circumference, the excrement, formerly dry and firm, now becomes moist and soft, and the appetite diminishes and becomes capricious. This state generally lasts three days, then suddenly the worm ceases to eat, and tries to get away from its food. It prolongs its head, and, changing its former lazy habit of scarcely moving except to get food, runs about in every direction, stepping from time to time, and moving its head (now transparent gold or white, according to race) like a blind person seeking the way.

These signs indicate that the worm is hunting a convenient place to spin its cocoon. The worm is now mature, and a spinning place should be ready to facilitate its metamorphosis. The humidity, which always exists at this time on account of the mass of litter, is especially dangerous to the worms; and it is increased if the worms do not all mature and mount at the same time, for those that remain below are wet by the liquid dejections of those that are the first to mount. For this reason do not put worms in the spinning place until they are perfectly mature. They then mount, and crawl around some time seeking a favorable place for their cocoons. Finding this they evacuate their digestive canal, and begin to throw around them an irregular net in which the cocoon spun later will be suspended.

PREPARATIONS FOR SPINNING.

A considerable loss may occur in the spinning place even when the rearing has been most successful. To avoid such loss observe the following precautions: (1) Prepare the spinning place in time; (2) arrange it so that the worms may regularly mount, and have abundant room; (3) have it well made, yet economical; and (4) regulate the heat and ventilate the room.

Any convenient dry bushy brush, odorless and free from gum, will serve to construct the spinning place; or if such is not available, bundles of straw, or shavings, or finely split up wood may be substituted. The best and most economical arrangement is small bundles of brush or straw placed upright between the feeding shelves, in rows, about 16 inches apart. The bundles are cut a half inch taller than the space between the shelves, and their tops are spread out to form arches, and to allow the worms plenty of room to spin (fig. 11).

Branches of elm, oak, birch, etc., are used to place the worms in the spinning place. These branches are spread over the shelves at the end of the fifth age. Very soon they will be covered with mature worms which have ceased to eat, and are turning away from the mulberry. In this way it is easy to select the worms that should be transferred.

If the worms are equally developed, in thirty or forty hours they will be shut up in their cocoons. The few that remain behind should be placed elsewhere; fed with fresh leaf on clean beds they will soon catch up with the others.

The fifth day after the mounting the worms that have not begun to spin should be placed in bundles of twigs and covered with straw or leaves, or put in a basket of shavings, where they will be forced to spin.

The temperature during the spinning should be 75° F., and the

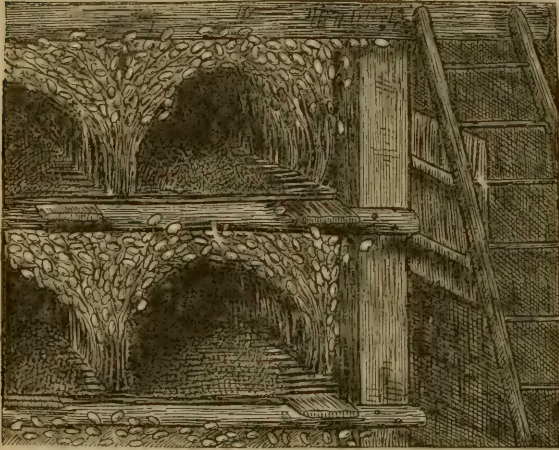


FIG. 11.—Arrangement of spinning places. (Redrawn from Pasteur.)

humidity throughout the rearing about 65°.

A good practical test of humidity is a saucer of salt; when the salt is moist, reduce the humidity. Carefully avoid disturbing the worms while spinning, and then, as during all the ages, keep the room as quiet as possible. The most scrupulous cleanliness should always be observed, both

with regard to the quarters and the attendants; to keep from raising dust, wipe the floor with a damp cloth instead of sweeping it.

PREPARING COCOONS FOR THE MARKET.

The transformation of the larva into the chrysalis is, according to temperature, completed in from seven to ten days from the time at which the first worm begins to spin. The cocoons are then said to be mature, and this is the best time to gather them. After the removal of the web the cocoons are sorted into three classes: (1) The perfect, (2) the double, and (3) the defective or spoiled.

In the United States, the absence of near-by markets makes it necessary that cocoons be prepared and stored away, sometimes for months or until they can be used. This preparing consists of killing the chrysalis and then drying the cocoon until no moisture remains to cause ferment and mildew and a consequent rotting of the silken thread. The killing of the chrysalis is usually termed "choking" or "stifling."

If the cocoons are not sold as soon as gathered, the chrysalides should be killed without delay unless they are to be reserved for reproduction; otherwise the moths may pierce the cocoons, rendering them unfit for reeling. Cocoons in which the chrysalides are still alive are usually termed "green" cocoons.

The chrysalides are usually killed either by heat or suffocation. The killing of the chrysalis is an important operation and one requiring care and judgment. If some are left alive, the moths will issue, thus rendering the cocoon of little value and staining the adjoining cocoons.

If the hot air of a stove is employed, the cocoons may be placed in the oven with the doors open, but great care must be used to see that the silk does not become scorched. If steam is employed, the cocoons may be placed in a colander over a vessel of boiling water. Do not allow the water to boil too hard, as only the steam must reach the cocoons.

A method of choking cocoons adopted by Mr. T. A. Keleher, of this Department, and now largely followed, consists of placing the cocoons in an air-tight box of about 24 cubic feet capacity and with them a saucer containing about half an ounce of bisulphid of carbon and leaving over night. It is best to open one or two of the cocoons to find if the chrysalides are dead; if not, the operation must be repeated. Care should be exercised that no fire of any kind be brought into the vicinity during this operation, as the bisulphid of carbon is very inflammable.

Cocoons to be dried should never be placed in layers of more than 4 inches depth. The shelf or tray that contains them should be perforated in order to allow air to circulate. They may be placed in the sun daily and dried in much the same manner that fruit is dried on a farm, carrying within doors at night or when rain threatens. At the Department a large fruit evaporator is being used with great success to dry cocoons quickly. Only a slow fire is maintained, and the heat is never allowed to rise very high. When a cocoon is thoroughly dried, the chrysalis can be crumbled between the fingers into a powder.

The thread of a cocoon is continuous with that of the web and diminishes in diameter within. Its length varies from 1,200 yards to 1,600 yards. Different races, sexes, and conditions of rearing often produce notable differences in weight of cocoons. Thus the weight may vary from 155 to 320 cocoons to the pound (340 to 700 to the kilogram) for "green" or newly spun cocoons or 465 to 960 for dried ones. *A thoroughly dried cocoon weighs but one-third as much as a newly spun one; or, in other words, the choking and drying of a cocoon causes it to lose 66 per cent of its original weight.*

In the United States, as the market price of cocoons at present is based on the rate of so much per dried pound, the producer should always ship them in this condition, as by so doing he saves practically two-thirds of the cost of transportation, does away with the danger of staining otherwise perfect cocoons, thereby lowering the grade of all, and at the same time gives a standard basis of weight, which must otherwise be assumed (if cocoons are unchoked) to be "green" from the time they reach the consignee. It will readily be seen that if cocoons are about 16 days old or thereabouts when received, the shrinkage has already been in operation for some time and the basis assumed is not a true one.

Often two or more worms are inclosed in the same cocoon. Cocoons formed from such collaboration are larger than single ones, irregular

in form, and cottony in texture. They can not be unreeled, but must be carded or combed out, and consequently are far less valuable than single ones.

In storing cocoons care should be exercised to protect them from rats and mice, which are very destructive to them. Ants occasionally do some damage, and the larvæ of the little beetle commonly known as the "museum pest" will gain a foothold whenever possible. Carbon bisulphid will usually dispel these two latter pests.

Cocoons may, if thoroughly dried, be placed in cloth bags and sent by mail, no bag to weigh more than 4 pounds gross weight. It is always risky to ship "green" or partly green cocoons in any manner, either by express or mail. The crushing of thoroughly dried cocoons in transit does not injure them for reeling purposes.

DISEASES OF SILKWORMS.

In every successful rearing of an ounce of eggs about 40,000 worms are hatched, and 30,000 succeed in spinning cocoons. The rest either die from casual wounds or from diseases incidental to restricted action. But sometimes whole chambers are destroyed by hereditary and contagious diseases, and it is of supreme importance to cultivators to learn how these scourges may be avoided.

In this limited treatise only a bare mention can be made of the most fatal diseases and of the necessary precautions to be taken to guard against them. The general cause of disease is the domestication of the worm. By using good eggs, however, and following the methods which are actually employed by successful rearers, remunerative results are usually obtained. To obtain good eggs it is necessary to adopt new methods. These are chiefly such as involve the use of the microscope.

Among the many diseases of silkworms, the principal ones are:

Pebrine, flacherie or flaccidity, gattine or macilenzia, calcino or muscardine, and grasserie.

PEBRINE.

This disease was first noticed in epidemic form in France in 1845. Since then it has appeared in Italy, Spain, Portugal, Turkey, Turkistan, the Caucasus, Kashmir, China, and Japan, threatening to destroy the silk industry.

Between 1833 and 1865 the annual crop of cocoons in France was reduced by pebrine from 57,200,000 pounds to 8,800,000 pounds. No remedy has been found for the disease, but the Pasteur microscopical selection of eggs, insuring the birth of healthy worms, is a sure preventive. The universal adoption of this method has made pebrine almost a thing of the past; and following Pasteur's line of research, means have now been discovered for avoiding every kind of silkworm disease.

Worms affected with pebrine develop slowly, irregularly, and very unequally. Black spots are the most marked outward characteristics of the disease; the internal signs are oval corpuscles only visible through the microscope.

Worms healthy born may contract pebrine during life, but this may not prevent their spinning, as the disease does not reach its climax before the chrysalid or moth stage, and in its incipency the worm is strong enough to spin, though the moth will produce diseased eggs. Hence the necessity of repeating the microscopical examination for each generation of worms.

Pebrine is not always visible, and when latent induces other diseases. When only one crop of cocoons is made annually, it is comparatively easy to resist pebrine, as the germ of it, outside of an egg, retains its vitality not longer than seven months. The disease takes thirty days to develop; therefore, if worms from pebrinized eggs can be made to spin within twenty-five days after hatching, they may yield a fair harvest of cocoons. In any case, however, it is only safe to use pure eggs, as pebrine, even in undeveloped stages, renders the worm more liable to contract all other diseases.

FLACHERIE, OR FLACCIDITY.

This is now the most dreaded disease among European silk-worms. In general, worms are struck with it after their fourth molt, when they are mature, or even while spinning (fig. 12).

Without any apparent cause, they begin to languish, then remain completely still, and shortly die. They blacken after death (fig. 13), and give out a disagreeable odor. Often entire chambers perish in a day. Again, the progress of the disease may be slow, the worms even spinning their cocoons, but, dying in the chrysalid state, they putrefy and soil the cocoon, thus greatly diminishing the value of the harvest. Flacherie is but another name for indigestion. Pasteur and many



FIG. 12.—Worms affected with flacherie dying in the brush (after Pasteur).

other scientists assert that flacherie is due to ferments and vibrións developing in the intestinal canal of the worm; other authorities maintain that the disease may exist independently of these. However, as these micro-organisms, in the majority of cases, play a prominent part in the development of flacherie, it is well to guard against them.

The principal causes of flacherie are: (1) Eggs being spoiled through careless preservation; (2) hereditary tendency; (3) overfeeding of worms; (4) wet, sweating, dewy, and fermented leaf; (5) leaf submerged in water or full of mud; leaf from a new plantation or from a shaded spot, coarse leaf, or change of leaf; (7) lack of ventilation; (8) excessive heat; (9) dust; (10) keeping worms too thick on trays; (11) accidental deaths of worms from injuries, these putrefying, and

the ferments thus created being communicated to other worms; (12) debility.



FIG. 13.—Worm which died of flacherie, putrefying after death. (Redrawn from Pasteur.)

If these causes are avoided, flacherie is not likely to invade a rearing. To prevent

contagion eggs should be dipped in a solution of sulphate of copper before being incubated; and in cleaning shelves and nets, wherever a dead worm is seen, powdered sulphate of lime or copper should be applied.

Unlike the corpuscles of pebrine, the microscopic organisms, which are probably the immediate cause of flacherie, remain alive from one year to another, and the dust of a rearing room may contain them in considerable quantities and become the means of infection. Hence, in cases of flacherie, immediately after the rearing, the walls, shelves, and all the implements should be washed in a solution of chloride of lime or some other germicide, and the room should be fumigated with sulphur.

GATTINE.

The external signs of gattine are indifference to food, torpor, dysentery, and emaciation. It attacks the worm in the first ages, and is especially manifested after a molt. Sometimes it is associated with flacherie, and, in its incipient stage, is confounded with this disease. Later the worm becomes extraordinarily emaciated and sufficiently transparent to be mistaken for a mature larva. The hooks of the prolegs are lengthened out and strongly attach the worm to whatever it touches. Meanwhile torpor creeps on and soon ends its life (fig. 14).

Worms having flacherie or gattine do not always die before mounting into the brush, and if the disease has not entirely invaded the organism they may even arrive at spinning. But instead of mounting with the promptness and rapidity of healthy worms, they stop hesitatingly at the base of the brush, then begin slowly to mount, stopping

on the first little twigs and distending themselves as though asleep, sometimes with the head turned towards the base. Again, especially in case of gattine, the worm wanders restlessly here and there, seeking as it were power to eject the silky matter, but too impotent to do more than throw out a scanty thread to weave a web or veil of a cocoon, in which it generally falls and dies.

Eggs free from disease and capable of resistance to disease are the prime requisite in guarding against flacherie and gattine.

The moment some deaths are noticed, proceed as follows: (1) Change beds immediately, briskly shaking the worms; (2) place the worms on disinfected shelves; (3) burn the diseased and suspected worms that do not mount on fresh beds; (4) if possible move the whole rearing to another room previously aired and disinfected, and also aired after disinfection; (5) do not feed during the three or four hours in which the change is being made; (6) keep up a little wood smoke in the room; (7) give a few scanty meals of light leaf; and (8) diminish the temperature a little.



FIG. 14.—Worm emaciated by gattine after the fourth molt. (Redrawn from Nenci.)

CALCINO, OR MUSCARDINE.

This disease, at first, has no visible appearance, but by degrees the vitality of the worm is impaired, and it eats and moves slowly. The body turns rose-colored or red, beginning with the stigmata, and then contracts and loses its elasticity, after which the worm stands still as though paralyzed, and finally dies 20 to 30 hours from the appearance of the first symptoms. After death the body dries up and is covered with a white efflorescence, causing it to look like a stick of white chalk (fig. 15); hence the name of the disease.



FIG. 15.—Calcinated worm. (Redrawn from Verson and Quajjat.)

Calcino is caused by a mold or minute fungus. There are two varieties of this fungus: *Botrytis bassiana* and *B. tenella*. They both attack the worm in the same way. The spores of the mold by chance get on the body of the worm when it is in a molting condition, and there take root, penetrating below the skin. The thread-like mycelium ramifies until it fills the entire body. Later some of the branches fructify on the surface, and the fruit bursting envelops the worm with innumerable spores resembling a white powder.

Each spore is capable of settling on a molting worm and giving it calcino, hence the necessity of taking steps to avoid contagion. Calcino is more contagious than other silkworm diseases. Darkness, stagnant air, dirt, warmth, and moisture are the five things that favor mold, and calcino is a mold.

The chief cause of the disease is neglecting to change the beds and keeping litter in and around the room. When only one or two worms have died from calcino all the shelves should at once be cleaned and divested of dead worms. The floor should be washed with a solution of sulphate of copper (1 to 200 by weight), and a pound of sulphur should be burned, or a strong wood smoke created in the room, which should then be shut up five or six hours, after which the worms should be fed. Should any worms die the next day the beds should again be changed and an ounce of sulphur burned. The quantity of sulphur fumes that would kill rats, bats, and lizards and even human beings does no harm to silkworms. No hesitation, therefore, need be felt in fumigating the rearing room with sulphur; but eggs and thread nets must not be subjected to sulphur fumes. Silkworms affected with calcino die before the moth stage; therefore, it is impossible for the disease to be hereditary. But loose spores of the mold creating the disease may get on healthy eggs. These may be washed off by a good bath of fresh water. Some recommend a bath with a solution of sulphate of copper (one-half per cent of copper). In cases of calcino the room should be disinfected immediately after the cocoons are gathered and the paper and brush used should be burned.

As calcino is never due to infected eggs no attention need be paid to the presence of spores of the *Botrytis* in the microscopic examination to select eggs.

GRASSERIE.

Silkworms having this disease become restless, bloated, and yellow. If punctured they exude a purulent matter full of minute polyhedral, granular crystals.

Grasserie is neither hereditary nor contagious. Unlike pebrine, flacherie, and calcino, it is not caused by microbes capable of multiplying and creating plagues. Grasserie does little harm to silkworms in Europe, but in warm countries, as in Bengal, sometimes assumes an epidemic form.

Worms first fed on mature leaf, and afterward on young leaf, are apt to take grasserie. The propagation of large trees is the best means of checking the disease. The main cause of the sporadic appearance of grasserie is mismanagement of the worms at the molting periods. Feeding should not be stopped before all the worms have begun to molt, and should not be recommenced until all the worms are well out of the molt; otherwise they are likely to have grasserie. This disease often leads to flacherie, and when it occurs in an exaggerated form indicates latent pebrine.

DIV. INSECTS.

U. S. DEPARTMENT OF AGRICULTURE.

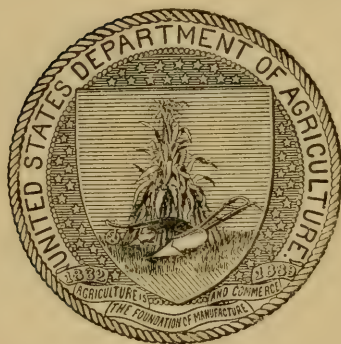
FARMERS' BULLETIN No. 171.

THE CONTROL OF THE CODLING MOTH.

BY

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WASHINGTON:

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1903.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., May 7, 1903.

SIR: I have the honor to transmit herewith the manuscript of a bulletin on The Control of the Codling Moth. This has been prepared in a condensed form by Mr. C. B. Simpson, a special agent of this office, from the extensive notes which he has taken during three years' investigation of the codling moth in the Northwest. On account of its probable value to apple growers I recommend that it be published as a Farmers' Bulletin.

Respectfully,

L. O. HOWARD, *Entomologist.*

HON. JAMES WILSON,
Secretary of Agriculture.

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THE CONTROL OF THE CODLING MOTH.

INTRODUCTION.

Everyone is familiar with the injury caused by the codling moth (*Carpocapsa pomonella* Linn), but very few know the insect which causes the irregular cavity in the apple and renders it unfit for use.

If injurious insects were classified according to the monetary loss caused by them, the codling moth would undoubtedly rank first among insects injurious to fruits, as it causes more loss than all other fruit insects combined. It has been estimated that from one-fourth to one-half of the apple crop of the United States is either totally ruined or materially injured by it. In many large areas this insect would cause a total loss if it were allowed to take its natural course. By the use of the best measures of control the larger part of this loss could be prevented, as many apple growers in badly infested regions are saving from 85 to 98 per cent of their fruit each year.

DISTRIBUTION AND SPREAD.

The original home of this insect was most probably in southeastern Europe—the home of the apple. It has followed closely the distribution of the apple until it is now found in almost every country in the world, and is injurious in every apple-growing section of any importance in the United States.

It is spread principally by the shipping of infested fruits. When the fruit is picked and packed the young larvæ are often inside, and when they complete their development they crawl out of the fruit and spin cocoons. When the moths emerge they fly to the nearest orchard and deposit their eggs. When orchards are but little distance apart the moths fly from one to another. The system of returning empty boxes in which apples have been sent to market has, in many localities, hastened the local distribution.

FRUITS INFESTED.

The apple is the natural food of this insect and sustains almost all the loss occasioned by it. In most localities the Winesap and Lawver apples are usually less attacked than other varieties, while the Pewaukee and Ortley varieties are usually badly attacked. The resistance of

these and other varieties is variable and depends upon many local conditions. Pears are next in the order of infestation. If apples are present, pears are usually not badly infested, but if there are few apples and large numbers of the insect, the pears suffer a heavy loss. This insect has been noted feeding on the quince, prune, plum, peach, and cherry, but never in sufficient numbers to cause any great amount of injury.

LIFE HISTORY OF THE INSECT.

A good knowledge of the life history of this insect is the first essential to its control. Every fruit grower should familiarize himself with its different stages by studying the insect in his own orchard.

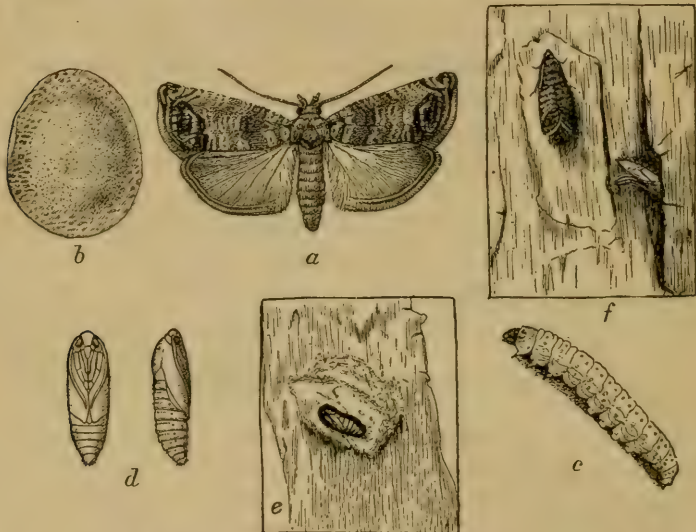


FIG. 1.—The Codling Moth: *a*, the moth or adult insect, slightly enlarged; *b*, the egg greatly enlarged; *c*, the full-grown larva, slightly enlarged; *d*, the pupa, slightly enlarged; *e*, the pupa in its cocoon on the inner surface of a piece of bark, reduced about one-half; *f*, moth on bark and empty pupa skin from which it emerged, about natural size (original).

HIBERNATION.

The codling moth passes the winter in the larval stage. The larvæ may be found encased in silken cocoons in cracks and holes in the trees and in houses where apples have been stored. In the spring these larvæ change to pupæ, from which the moths emerge about a week after the apple is in blossom.

THE MOTH.

The adult insect or moth (fig. 1, *a*) is but little known among fruit growers and other moths are often mistaken for it. It varies somewhat in size, but the maximum spread of its wings is about three-

fourths of an inch. The front wings are of a brownish-gray color and are crossed with lines of gray scales, giving them the appearance of watered silk. At the tips of the wings there is a large brown spot, in which are many scales of bronze or gold. The hind wings are grayish brown in color. Taken as a whole, the coloring of the moth is such that when resting on old grayish bark it is so like the bark that it is not easily distinguished.

The moth lays her eggs, a few days after emergence, on the leaves of apple or other food plant, or on the fruit. A majority of the eggs of the first generation are laid on the leaves, while the greater part of those of the second generation are laid upon the fruit.

THE EGG.

The eggs of this insect were never noted until within comparatively recent years. They are of a pearly white color and are like thin convex disks. Around the edge there is a coarse network of ridges, while toward the center these ridges are finer.

A red ring, which indicates the embryo, appears in the egg a few days after it is laid. In about eleven days (varying somewhat with temperature) the young larva breaks its way out of the shell and seeks to enter the fruit.

THE LARVA.

This is the most important stage of the insect, for not only does it do its injury in the larval condition, but that is the stage in which it is most amenable to remedial measures.

Recent work tends to show that a large number of the larvæ which hatch from eggs deposited on the leaves eat small portions of the leaves before finding fruit. The larvæ have some difficulty in entering the smooth sides of the fruit; hence they usually enter at the calyx or take advantage of some irregularity in the surface. About 80 per cent of the larvæ of the first generation enter the fruit by way of the calyx, while the majority of the second generation enter at the sides, especially where fruits are touching. Upon entering the fruit, the larva feeds immediately under the surface for a few days and then commences a tunnel toward the center of the fruit, where it eats out a large cavity. Frass and excrement which are thrown out characterize a wormy fruit. The larva, which is well known to all fruit growers, lives in the fruit about twenty days and grows pinkish or whitish, until it is about five-eighths of an inch in length (fig. 1, *c*), when, being full grown, it makes a tunnel to the outside of the fruit, the entrance of which is filled with frass and silk. When ready to leave the apple this plug is pushed out. The larva then crawls out and immediately seeks a place in which to spin its cocoon.

THE COCOON.

The places of spinning the cocoon vary with the surroundings. Cocoons have been observed in the following places: In holes and cracks in the trunks and branches of the trees; under rough bark; in the fruits (though rarely); in the cracks in the ground around the tree; on or between the clods among the fallen fruit; under bands or anything else resting on or against the tree; in cracks and angles of the walls and roof of the building in which apples are stored; under shingles of buildings near apple trees; in fence posts and under pickets of near-by fences; in paper or other rubbish on the ground; and in various other places. The cocoons of the first generation are composed entirely of silk, while in those of the second generation are incorporated bits of wood and bark. The larvæ inside the cocoons transform into pupæ in about six days from the time of spinning the cocoon.

THE PUPA.

The pupa (fig. 1, *d*) is yellowish at first, but changes to a brown, and later to a bronze color. The eyes, antennæ, mouth parts, wings, and legs of the adult insect are apparent. The movable abdominal segments are armed with two rows of spines. In about twenty days from the spinning of the cocoon the pupa, aided by the spines, pushes its way out of the cocoon. The pupa skin splits and the moth emerges (fig. 1, *f*), lays its eggs, and gives rise to another generation. The average life cycle of the insect is about fifty days.

GENERATIONS OF THE INSECT.

It has been found that in the principal apple-growing sections of the northern part of the United States the insect has one generation and often a partial second. In the warmer portions of the East and the West two generations are found. In the warmest parts of the West a partial third generation has been distinguished. Where two full generations occur the second is much more numerous and destructive than the first.

NATURAL ENEMIES.

There are many natural enemies of the codling moth which may be encouraged with advantage. It has often been noted that no larvæ can be found under the rough bark of the trees in the spring, while many are found in the cracks and holes in the trunks, branches, and stubs. Under the rough bark many cocoons can be found from which the larvæ are missing. A telltale hole made by a woodpecker can always be found. Destroying or rendering unsuitable the more secure places for spinning, thus forcing the larvæ to spin cocoons where the birds can get them, will result in destroying many of the insects.

MEASURES USED AGAINST THE CODLING MOTH.

The first essential in using measures against this insect is for the apple grower to familiarize himself with its life history. By doing this he is better prepared to understand the remedial measures recommended, and can modify them to suit his local conditions.

The means of control readily fall into two divisions—(1) preventive measures and (2) remedial measures.

In many newly settled districts of the West this insect has not yet made its appearance. By keeping all used apple boxes and infested fruit out of the district it may be a long time before the insect obtains a foothold. If it is present in small numbers, it may be practically exterminated by a strenuous application of the measures of control, but if present in great numbers it is impracticable to attempt its extermination. In many localities, by reason of the cold climate, the injury amounts to but little; in some years it may be no more than 5 per cent, while in others it may amount to 20 per cent. By using methods of control this damage can be materially reduced.

PREVENTIVE MEASURES.

Preventive measures are those means of control which are not only efficient against this insect, but are valuable in increasing the productiveness of the orchard, and the size, appearance, and quality of the fruit.

Measures for Use in Old Orchards.

The preventive measures to be used in an orchard that has just come into bearing are quite different from those required in one that has borne fruit for many years. The old neglected orchards are familiar objects in every section of the United States.

The writer has in mind two such orchards of different types of about 500 trees each. One is in the far West in an arid section, and the other is in the East in a humid section. Both are in localities of about the same average temperature. The Western orchard is about 18 years old; the trees are so close together (18 feet) that the branches of one tree touch those of the surrounding trees. The orchard has not been irrigated for many years; the soil is sandy, and on it grow many weeds; the bark of the trees is rough, the trunks and branches are cracked, and where branches have been cut off either holes or stubs remain. From lack of moisture the trees make but little growth and a few have died. The fruit is abundant, but undersized. For the past three seasons this orchard has been under the observation of the writer, and in that time not over 3 or 4 boxes of good apples free from the work of the codling moth have been produced.

In the Eastern orchard the trees are in sod and about 40 feet apart. There are many stubs of broken branches in which the larvæ hibernate. The fruit has always been abundant, but is practically all infested by this insect.

The woodpeckers have done much effective work in both these orchards by digging out and eating the larvæ. Other insects may be attacking the trunks of the trees or eating the leaves. Practically no revenue is derived from either of these orchards, but, on the contrary, they are a constant source of loss.

Many farmers who have orchards similar to those just described believe that the only thing to be done is to cut down the trees and start new orchards instead of renovating the old. These orchards can be restored quite easily and made to produce profitably for many years. Work should be begun late in the fall or early in the spring, and the treatment should be about the same in both cases, except that the Western orchard should be irrigated freely, and every second tree should be cut out. In both orchards the soil should receive a very shallow cultivation for a year and a dressing of manure. The following year cover crops, such as cowpea or red clover, should be sown and plowed under, and this should be repeated every few years. Branches should be cut out where they are matted together, thus allowing access of the sunlight and spraying solution. In the West a thick foliage is often an advantage in protecting the fruit from the sun and thus avoiding sunburn. The dead branches and stubs should be cut away and burned. It is highly important that the cut ends be smooth and dressed with shellac varnish or grafting wax. All of the rough bark should be scraped from the trunks and larger branches. The holes in the tree should be filled with plaster or cement, thus confining all larvæ that are in them and preventing others from entering later in the season.

If proper attention is given an orchard when it is young, no such work will ever be necessary.

Measures for Use in Young Orchards.

If a young orchard is to be planted in a badly infested locality, this insect must be considered from the very first if any degree of success is to be achieved. The question of varieties is largely a question of climate, soil, and the demands of the market. The Winesap and Lawver varieties are always resistant to this insect, and the Ortley and Pewaukee are always badly infested. Late winter varieties are usually less infested than the fall varieties, and in some sections of the country the early apples are harvested before the second generation of the insect attacks the fruit. The trees should never be planted nearer together than 30 by 30 feet in order that a spraying machine and wagon may have plenty of space between the rows. They should

lean toward the southwest, so that the tops will shade the trunks, thus in a measure avoiding sun scald, the effects of which furnish secure places in which the codling moth larvæ can spin their cocoons. The pruning of a tree when it is young is of the utmost importance. If the tree grows too high it is difficult to spray when it is full grown; if too low the branches lie on the ground and the same difficulty occurs. It is expensive to pick the fruit from high trees, and when the lower branches are on the ground the fruit upon them will be uncolored. A good average between the high and the low trees is to be desired. If only two or three main branches grow out from the trunk they will nearly always split apart under the weight of a full load of fruit. When such a branch is put in place and held either by a bolt or a wire, the crack made by the splitting is an attractive place for the insects. In many orchards it has been observed that trees thus injured always have a higher percentage of wormy fruit than those which are uninjured. This splitting may be prevented by pruning, so as to cause many branches to form the body of the tree, and cutting back about half of each year's growth, so as to make the tree stocky and able to bear the excessive weight; by thinning the fruit; or by propping the limbs.

By planting clover in an orchard, not only is the soil benefited, but the ground is kept moist; and because they dislike moisture the larvæ will not spin cocoons in the ground around or near the tree.

Thinning fruit.—In the Pacific Northwest the thinning of apples is a practice that is badly neglected. As a result, much of the fruit is small, uncolored, and consequently inferior in value. The advantages of thinning in producing better fruit are too well known to need discussion. All of the terminal clusters should be thinned to one fruit and fruits should not be allowed to grow closer together than 6 inches. The thinning should be done when most of the codling-moth larvæ of the first generation are in the fruit. In the Pacific Northwest thinning should be done between June 15 and July 1. In other localities this work may be done earlier or later, but observation can determine the time with reasonable accuracy. In thinning, special care should be taken that as many of the wormy apples be picked as is consistent with the rapidity of the work. The wormy fruit thus removed from the trees should be buried, being covered with at least 6 inches of earth. It has often been recommended that the windfalls be gathered every few days and destroyed. In a small orchard this is practicable, but in a large commercial orchard it would be far too expensive.

Packing fruit.—The place of packing the fruit is of the greatest importance when the codling moth is considered. The best plan, and the one which is being generally adopted among the best Western orchardists, is to have the packing done in the orchard. A movable packing table is made upon runners and this is drawn through the

orchard. As the apples from two rows of trees on either side are picked, they are carried to the table by the pickers. By this method the apples are not moved any considerable distance until packed, and the danger of bruising the fruit is thus reduced to a minimum. If infested fruit is taken into a packing house, the larvæ crawl out of the fruit and spin their cocoons in the cracks and angles of the building. In the spring the moths emerge and fly to the orchards. By packing in the orchard the wormy fruit is piled up, and the larvæ for the most part spin cocoons among the apples.

Many apple growers make the mistake of selling or trying to sell wormy apples as first-class fruit. It is a difficult thing to pack a box or barrel of apples and not put in a single imperfect apple, but the ideal of perfect fruit should be the growers' guide. Second-class apples should be packed and shipped as quickly as possible. The culls and windfalls should be promptly made into cider for vinegar or disposed of in some other way, thus preventing the escape of the larvæ. If they are not so used, they should be buried. Experiments in burying culls and windfalls have shown that when the larvæ leave the fruit they spin their cocoons on or between the apples and rarely try to reach the surface of the ground. If the larvæ survive, the moths which emerge die, as they can not reach the surface of the ground.

Storing fruit.—It is a great mistake to store infested fruit near an orchard, as when the moths emerge in the spring they fly to the orchard, and in many cases a large percentage of the fruit near the storehouse is infested. The writer has studied several cases where this was true, and in each case the resulting loss could have been averted. If the fruit must be stored, the house in which it is stored should have no cracks or holes through which the moths can escape. A tight house can be fumigated with hydrocyanic-acid gas or with sulphur. A simpler way is to crush the moths when they have gathered on a window or on a screen; or, if left in the storeroom, they will die in a week or so.

REMEDIAL MEASURES.

Remedial measures against the codling moth are those from which little or no benefit is derived, except that of saving the fruit from attacks of the insect.

Remedies of Little or no Value.

It is sometimes as well to know what not to use against an insect as it is to know what to use. The following remedies have been at various times suggested and have been found to be of little or no value: Moth balls hung in the trees and supposed to keep moths away; smudging orchards with ill-smelling compounds; plugging the trees with sulphur; plugging the roots with calomel; banding trees with tarred

paper to keep the larvæ from crawling up the tree; trap lanterns; baiting the moths with mixture of vinegar and molasses; spraying with ill-smelling compounds; spraying with water; and electric lights as a repellant of the moth. These so-called remedies have been tried so often that a fruit grower is simply wasting his time and money when he uses them.

Spraying with Arsenical Insecticides.

The efficiency of sprays against this insect was discovered in spraying for canker worms, which feed upon the leaves of the apple. Since that time the machinery and the solutions used in spraying have been greatly improved, and now this method is well known to be the best and most efficient.

Many farmers have a deeply rooted objection to spraying on general principles. They have never sprayed, and many of them are proud of the fact that they do not spray their orchards, even if they lose the larger part of their fruit which otherwise might have been saved. The more progressive and business-like apple growers are the staunchest advocates of spraying, and their efforts are uniformly successful. Experience gained by several years of spraying always brings about greater efficiency and a reduction of expenses. A fruit grower who wishes to begin spraying can well afford to study the spraying operations in other orchards and familiarize himself with the general methods.

Spraying Machinery.

The kind of spraying outfit depends upon many factors, the principal one being the number and size of the trees.

Hand-power outfits.—For an orchard of 1,000 trees or less the writer would advise the use of a hand-power outfit. The capacity and cost of this machine should depend upon the size of the orchard. There are many excellent makes of spray pumps upon the market, and a pump can be easily chosen to suit the conditions in various orchards. The working parts of the better and more expensive pumps are made of brass or bronze. It is desirable that a pressure gauge be attached to the pump, in order that the man pumping may keep up a constant pressure. More than two lines of hose result in confusion and cause loss of time in an orchard. Bamboo or iron extensions should be used in order to reach the tops of the taller trees. There are two types of nozzle, either of which may be used for this work—(1) those which give a fan-shaped spray and (2) those which produce a cone-shaped spray. The former is better adapted to long-range work and the latter to close-range work. As many as 3 or 4 of these nozzles may be used to advantage on one line of hose, but 2 is the usual number. It is a great advantage to have the nozzles set at an angle from the axis of the extension, as by simply turning the extension the spray can be

thrown in all directions among the branches. The spray must be applied with great force (60 to 100 pounds or more) in order that the stream be broken into a fine mist.

The tank may vary from a 50-gallon barrel to a tank of 250 gallons capacity, which may be mounted on an ordinary wagon; a barrel may be hauled on a sled. The tanks should be solidly built and held together with iron rods. If the trees are tall, it will be found to be of great advantage to have a platform erected on the wagon upon which the

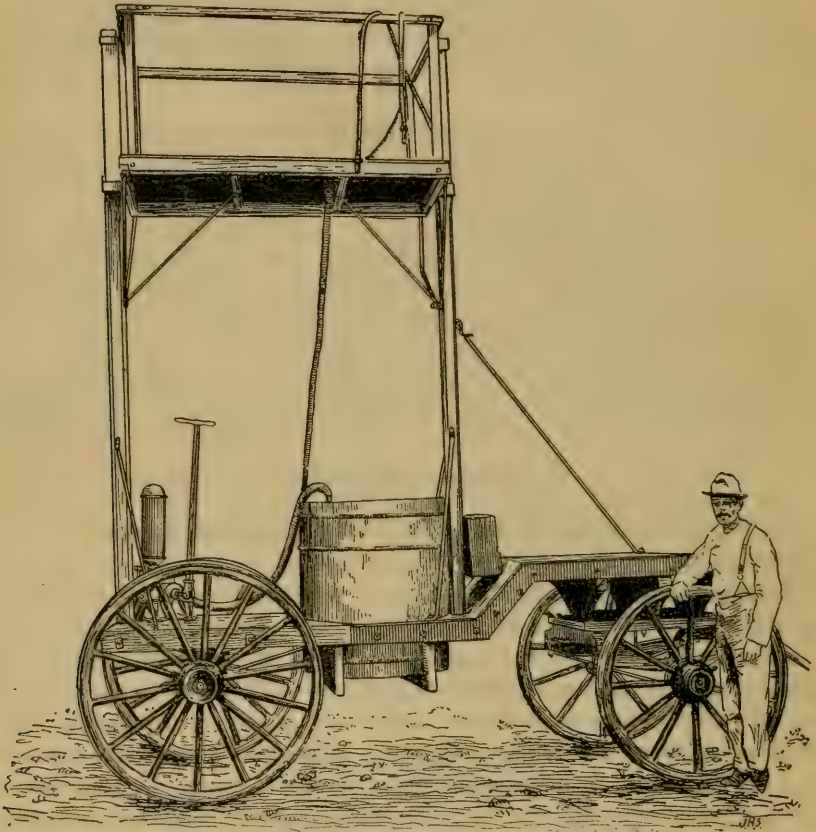


FIG. 2.—Spraying outfit for treating tall trees—(after Gould).

men can stand (fig. 2). The capacity of the hand-power outfit depends upon many factors, as distance of water supply, size of trees, and number of men and nozzles. Three men with a 200-gallon tank and 2 lines of hose, each fitted with 2 nozzles can spray about 250 average-sized trees per day.

Gasoline-power sprayers.—If an orchard of more than 1,000 trees is to be sprayed, it will be found advisable to use a gasoline-power outfit (fig. 3). Many dealers in spraying apparatus have placed machines

of this kind upon the market. A majority of these are well adapted to the work for which they are intended, but many valuable improvements can yet be made which will increase the efficiency of these machines with but little cost. In general, the size of engine to be preferred is 1 horsepower. The cooling tanks used with the engines are intended to be used when the water can not be renewed frequently, and are about 1 foot in diameter. In spraying, the water can be renewed often and the weight can be reduced considerably by making these tanks of a much smaller diameter. Purchasers are always given full directions in regard to the care and running of the engine, so that ordinarily but little difficulty is met. The engine is best placed at the rear end of the wagon frame and the pump as near to it as possible. There are several types of pump which can be used in this connection. Brass working parts which can be easily

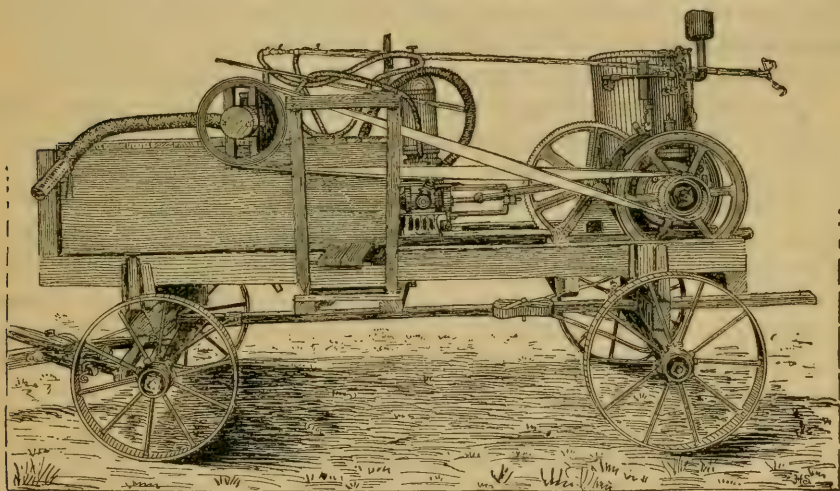


FIG. 3.—Gasoline power spraying outfit (original).

removed are preferable. A pressure gauge and a large air chamber are necessities. For filling the tank another pump of the “low-down” type can be used advantageously when the water supply is to be drawn from a stream or irrigating ditch. This extra pump and necessary connections can be purchased for about \$20, and in a season will pay for itself many times over by the saving of time and labor. The gasoline engines are usually fitted up for running such a pump by means of a connecting rod which can be attached to the piston of the pump. While filling the tank the spray pump can be disconnected or, more easily, the suction hose can be taken out of the tank. The tank may be made of wood or of galvanized iron. It should be thoroughly braced and should never be made to hold over 150 gallons. It should be placed nearest the horses, because of its great weight when full of the spraying solution. The best agitator is a paddle wheel, with pad-

dles placed at an angle on a vertical shaft. By means of bevel gearing and a belt, power is obtained from the engine. The engines, pumps, and tank are mounted on a solid frame, which is placed upon a low wagon. The low steel-wheeled wagons are highly preferable, as the tires, which should never be less than 6 inches wide, prevent the machine from sinking into the soft earth. Platforms can be built on the sides, upon which the operator can stand. With a bamboo extension and long-range nozzles set at an angle every part of the trees can be easily sprayed. Only two men are needed to operate this outfit: One drives, the other starts and stops the engine, and both spray. With this machine 700 8-year-old trees can easily be sprayed in one day; by rushing, more may be done. It takes from four to five minutes to fill the 150-gallon tank and from thirty to forty minutes to spray out the same amount on from 60 to 80 trees, using about $2\frac{1}{2}$ gallons per tree. In an irrigated orchard care must be taken to let the ground become dry before spraying is done, because if the ground is soft the machine may mire down, especially when the tank is full.

The cost of these machines varies with the cost of the engines and pumps. The machine with which the writer is most familiar cost \$320, including a \$40 wagon. With good care and proper repairs these machines ought to last many years. In a working day of ten hours a 1-horsepower engine consumes about a gallon of gasoline. The engine can be made to pay for itself by other uses which may be made of it, such as running the cider press, the feed cutter, the cream separator, or the wood saw, turning the grindstone, and doing numerous other things. The wagon can be used for other purposes when not needed for spraying.

Spraying materials for use against the codling moth.

Contact insecticides.—The insecticides which kill by touching the insects, such as kerosene emulsion and whale-oil soap, applied frequently, have in a few experiments been found efficient against this insect. On account of the expense and the necessity for frequent application they have never been used to any extent.

Arsenical sprays.—The arsenical sprays contain arsenic as the poisonous ingredient. There are several of the spraying compounds upon the market and many others which the fruit grower can prepare himself.

Paris green is probably the best known of these arsenicals. It is a definite chemical compound of arsenic, copper, and acetic acid and should have a uniform composition. It is a rather coarse powder and has the fault of settling rapidly. In the East it costs 20 cents a pound, while in the West the cost is 25 cents.

Paris green may be prepared for spraying as follows:

Paris green.....	pounds..	1
Lime.....	do....	1 to 2
Water	gallons..	100 to 250

The lime should be fresh and should be slacked in quantities as needed. Mix the Paris green with a little water until a paste is formed, and then add this to the required amount of water, to which the lime has been added. A good average strength to use is 1 pound to 150 gallons, but it must be weaker on trees with delicate foliage, such as peach. Many fruit growers are using it on apple trees as strong as 1 pound to 100 gallons.

Scheele's green is similar to Paris green, but differs from it in lacking the acetic acid. It is a much finer powder than Paris green and more easily kept in suspension, and it costs only about half as much.

London purple is a waste product in the manufacture of aniline dyes and contains a number of substances, the principal ones being arsenic and lime. It is variable in composition, is not so effective as the other poisons, and is now but little used for spraying.

Scheele's green and London purple are prepared for spraying in the same way as Paris green.

White arsenic compounds, made by combining other chemicals with white arsenic, form a class of excellent spraying materials. Arsenic used alone seriously burns the foliage.

Arsenite of lime.

White arsenic.....	pounds..	1
Lime.....	do....	2
Water	gallon..	1

These ingredients are boiled together for not less than half an hour, as it is quite difficult to make the lime and arsenic combine. Pour in water enough to replace that lost by evaporation. To every 40 or 50 gallons of water use 1 pint of this stock solution. It is advisable to add more lime to the spraying solution, in order that there will be less danger of burning the foliage.

Arsenite of lime with soda.

White arsenic.....	pounds..	1
Sal soda (crystal)	do....	4
Water	gallons..	1

The above ingredients are boiled until dissolved, which will be in a very few minutes, and the water lost by evaporation is then replaced. To 40 or 50 gallons of water a pint of this stock solution and 2 to 4 pounds of freshly slacked lime are added. This excess of lime is always desired by fruit growers, as they can then see by the amount

and distribution of the lime on the foliage how well the spraying has been done. This formula has been thoroughly tested by the writer and others and has been found not only as efficient as the other solutions, but far cheaper.

Arsenate of lead.

Arsenate of soda	ounces..	10
Acetate of lead	do....	24
Water	gallons..	150-200

These ingredients should be dissolved separately and then poured into the tank containing the water for spraying. They unite readily, forming the flocculent white precipitate of lead arsenate. This is easily kept in suspension and can be used in excessive strengths on delicate plants without the addition of lime. There are several preparations of lead arsenate on the market which are excellent, some being in a wet state and others in dry, powdered form. The wet preparations are preferable, as the dried arsenate does not give such a filmy and adhering coat to the foliage.

At all times the greatest care should be taken to prevent accident with these compounds, which are of the most poisonous nature.^a All packages, boxes, or bottles containing these materials should be plainly labeled and kept in some place that can be securely locked. The utensils in which the mixtures are prepared should be thoroughly cleansed.

When it is desired to use a fungicide with any of these solutions the arsenites are added to the Bordeaux mixture in the same proportion as it would be added to water.

Cost of Spraying Material.

The cost of the different arsenical compounds varies in different sections of the country in accordance with the freight rates and the quantity purchased.

^a Although no accidents have ever resulted from the use of arsenicals in spraying, it is well enough to know what to do in a case of accidental poisoning. If any evil effects are noted in case of persons who constantly handle these poisons, a physician should be consulted. If by any mistake or carelessness a small quantity is swallowed, an antidote should be employed without delay. Ferric hydrate, which forms an insoluble compound with arsenic, is the best; lime water may be used, but is less effective. Some emetic, such as mustard in warm water, should be taken immediately after the antidote. The Ferric hydrate should be freshly prepared by adding strong ammonia to the solution or tincture of ferric chlorid. Both chemicals are kept in all drug stores. In preparing the ferric hydrate, continue to add ammonia until, after being well shaken, a faint odor of ammonia can be observed; an excess of this ingredient is decidedly injurious. Persons who use arsenical sprays are advised to keep a small bottle of each of the chemicals used in making ferric hydrate on hand for use in case of emergency.

The cost of 600 gallons of the different spraying solutions just described is, in the far West, as follows:

Paris green:

Paris green, 4 pounds at 25 cents	\$1.00
Lime, 8 pounds	.04
Total	1.04

Scheele's green:

Scheele's green, 4 pounds at 12½ cents	.50
Lime, 8 pounds	.04
Total	.54

Lime arsenite:

White arsenic, 1½ pounds at 10 cents	.15
Lime, 3 pounds	.015
Additional lime, 12 pounds	.06
Total	.225

Lime arsenite with soda:

White arsenic, 1½ pounds at 10 cents	.15
Salsoda, 6 pounds at 1½ cents	.09
Additional lime, 6 pounds	.03
Total	.27

Lead arsenate:

Arsenate of soda, 2½ pounds at 10 cents	.25
Acetate of lead, 6 pounds at 12 cents	.72
Total	.97

Prepared lead arsenate, 36 pounds at 20 cents \$7.20

Any fruit grower can estimate what these spraying solutions will cost him by finding what these chemicals cost in his section. The cost of the prepared lead arsenate is prohibitive for a commercial orchard, but in case of a home orchard of but few trees it saves a large amount of labor and is much used in such cases.

Cost of spraying.

The cost of spraying is practically nothing when compared with the benefits derived. As in other lines of work, exact methods and cutting off every unnecessary expense will reduce the cost considerably. The estimates given herein are based on data obtained in the field when spraying operations were in progress. The spraying of 1,000 trees once is taken as a basis for calculations under Western conditions. In localities where labor and material are cheaper the cost will be considerably lower.

Hand-power spraying outfits can be purchased and put in working order for from \$15 to \$75. The gasoline-power outfits can be purchased complete for from \$280 to \$400. A hand-power sprayer, if used for arsenites alone and given good care, ought to last five or six years with but few repairs, and the gasoline sprayer can be made to last as long. By using the engine for purposes other than spraying it can be made to pay for itself.

The principal cost of spraying is the labor, as the material is comparatively a small item. The cost of spraying 1,000 8-year-old trees in the West once with arsenite of lime with soda using $2\frac{1}{2}$ gallons per tree is as follows:

Hand-power outfit:

Man and team 4 days, at \$3.50	\$14.00
Two men 4 days, at \$1.50 each	12.00
Materials	1.12
Total	\$27.12

Gasoline-power outfit:

Man and team $1\frac{1}{2}$ days, at \$3.50	5.25
One man $1\frac{1}{2}$ days, at \$1.50	2.25
Materials	1.12
Gasoline, $1\frac{1}{2}$ gallons	.55
Total	\$9.17

The above estimates are for labor in the far West and would be much less in the East. It is considered that the team and labor are employed at the current rates; but as teams and men are already employed on all farms, this cost is far in excess of what it would actually cost the farmer. According to the preceding estimates it would cost 2.7 cents per tree with hand power and .9 cent per tree with gasoline power. The additional cost of spraying to the fruit grower would be about 1 cent per tree with hand power and about $\frac{1}{2}$ cent per tree with gasoline power.

How to Apply the Spray.

The spray should be applied to the leaves and foliage so that a thin coating will remain after the water has evaporated. To do this the spray should be applied with great force so as to form a dense mist. At all times the solution in the tank should be kept thoroughly agitated, especially if Paris green is used. Probably the most rapid progress in spraying can be made in the following way: Drive the outfit between two rows and spray half of each tree in each row. The routes followed in an orchard should be governed by the position of the water supply. If the wind is blowing it is best to go parallel with it rather than at right angles to it, and advantage may be taken of the wind by allowing it to blow the mist into the trees.

Time of application of spray.

The most important consideration in spraying is the time of the application. The time of application for the codling moth should depend entirely upon the stage of the insect, as the greatest efficiency is obtained by spraying just when the larvæ are entering the fruit or immediately before. The sprayings may be designated as "early" and "late." The early sprayings are directed against the first generation of the codling moth. Two of these sprayings are advised, one a few days after the blossoms have fallen and before the calyx closes, and the other two weeks to a month later, when the larvæ are entering the fruit. In cases of bad infestation, when the preventive measures have been neglected, another spraying may be added. In the West the evidence goes to show that the spraying immediately after the blossoms fall is not so effective as it is in the East. Some are of the opinion that it should be dispensed with; but in view of our lack of knowledge on this point, the writer does not think that the evidence at hand fully justifies discouraging this spraying in the West.

The later sprayings are directed against the larvæ of the second generation when they are entering the fruit. The time this generation enters the fruit varies with the locality and the seasons in the same locality, but it is easily found by watching the fruit for the first new entrance holes; or spraying may be commenced about twenty-one days after the date when the largest number of larvæ of the first generation are ready to spin their cocoons. The larvæ of the second generation usually begin to enter the last week in July, and the majority enter in August, while a few enter in September. The number of sprayings to be made against this second generation depends upon the efficiency of the preventive measures and the early sprayings. Two sprayings are usually sufficient; but if infestation is bad, three should be made. The quantity of lime used in the last spraying should be reduced to the minimum required, as the lime on the ripe fruit reduces its market value.

Light showers have but little effect in washing away the spray, but a continued rain or a heavy shower makes it necessary to repeat the spraying. The lead arsenate is less affected by rain than the other compounds.

The young larvæ are killed by the poison they eat before they have entered the fruit. They get it in the calyx, on the sides of the fruit, or on the leaves. Recent work tends to show that a great many get the poison by nibbling the poisoned leaves.

BANDING.

The use of bands to trap the full-grown larvæ of this insect was the only remedial measure of value before the use of arsenical sprays was

discovered. When an orchard has been given good care, preventive measures have been fully carried out, and spraying is thoroughly done with a gasoline-power outfit, it is unnecessary to use bands. If, however, the trees are old, have cracks and holes in the trunks and branches, and are close together, so that the spraying can not be well done, it is quite necessary to use these bands; or if it is desired to bring the insect under control in a badly infested orchard, the bands can be used with good success as an additional method to spraying.



FIG. 4.—Large apple tree properly banded for the codling moth (original).

Banding for this insect in general is simply offering a good place, in which the larva will spin its cocoon and killing it after it has done so. Cloth bands, from 10 to 12 inches in width, are folded once lengthwise and placed around the tree. They can be fastened in such a way as to be easily removed and replaced by driving a nail through the ends and then nipping off the head at an angle so as to leave a sharp point. If a tree is large, one band should be placed on the trunk and one on each of the larger limbs. (Fig. 4.) Cloth bands of any heavy, dark-colored stuff are much preferable to bands

of hay or paper. When bands are used, other places in which the larvæ might spin cocoons should be destroyed or rendered unsuitable. It is, of course, a most important point that the larvæ which go under the bands be destroyed. To accomplish this the bands should be inspected regularly at intervals of ten days. At best, banding is but little effective in badly infested localities if used alone, but it is a most valuable adjunct to spraying.

CONCLUSION.

The results secured against this insect by these methods under the different conditions found in the various apple sections of the United States are very satisfactory. In the infested sections of the far West, if no measures are used, from 85 to 100 per cent of the fruit is injured. By an intelligent application of these preventive and remedial measures many practical tests show that from 85 to 98 per cent of the fruit may be saved.

FARMERS' BULLETINS.

The following is a list of the Farmers' Bulletins available for distribution, showing the number and title of each. Copies will be sent to any address on application to any Senator, Representative, or Delegate in Congress, or to the Secretary of Agriculture, Washington, D. C.

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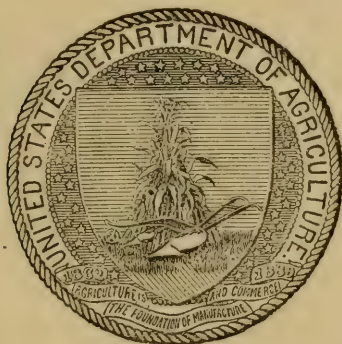
FARMERS' BULLETIN No. 172.

SCALE INSECTS AND MITES ON CITRUS TREES.

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., April 17, 1903.

SIR: I have the honor to transmit herewith for publication an account of the more important scale insect and mite enemies of citrus trees, prepared by Mr. C. L. Marlatt, entomologist in charge of experimental field work. This bulletin is a somewhat condensed revision of the article under the same title published in the Yearbook of this Department for 1900. The classes of insects mentioned are the most important enemies of the citrus fruits, and this Office is in receipt almost daily of inquiries concerning them. To meet the need for more widespread dissemination of information on the subject, this paper is recommended for publication in the Farmers' Bulletin series. The information conveyed will be of special service in California, throughout the Gulf region, including Florida, and in our new sub-tropical possessions.

Respectfully,

L. O. HOWARD,
Entomologist.

HON. JAMES WILSON,
Secretary of Agriculture.

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SCALE INSECTS AND MITES ON CITRUS TREES.^a

INTRODUCTION.

The scale insects, or bark-lice, are the most important insect enemies of citrus, as they are also of most other subtropical plants. They are, as a rule, small and inconspicuous singly, but they multiply so rapidly that very soon an entire plant becomes infested—trunk, limbs, leaves, and fruit. The attacked tree is rarely killed outright, but its growth may be almost completely checked and its fruit rendered valueless.

Next in importance to the scale insects are the mite enemies of the orange and lemon, as represented by the mite which causes the rusting of the orange in Florida and the silvering of the lemon in California, and also the leaf mite, known from its coloring as the six-spotted mite of the orange. These mites occur with the scale insects, are subject to similar remedies, and may properly be considered in the same connection.

Of very great importance to the Florida grower of citrus fruits is the so-called white fly, the latter not being a scale insect in the ordinary acceptance, but in the essential features of life history and habits coming in the same category, and hence properly considered with the true scale insects.

There are many insect enemies of citrus plants other than the scale insects and mites, but, for this country, at least, these others, in the main, have no great economic importance, or are only very occasionally abundant enough to be especially destructive.

Occurring about the orange and other citrus trees will also be seen many other insects which play a beneficial rôle, preying upon or parasitizing the scale insects living on these trees. It is very important to make the acquaintance of these beneficial species, more particularly to avoid, whenever possible, killing them in the warfare waged against the injurious ones.

^a No one can discuss the insect enemies of citrus plants without acknowledging indebtedness to the very comprehensive and valuable work, now long out of print, prepared by the late H. G. Hubbard and published by this Department in 1885, under the title "Insects affecting the orange." The practical side of Mr. Hubbard's work is especially to be remembered, and particularly that he devised kerosene-soap emulsion, which, with allied washes, has for many years been the leading means of controlling scale insects.

INFLUENCE OF CULTIVATION, PRUNING, AND CLIMATE.

With the orange and lemon as with other plants, negligent cultivation and improper care, or any unfavorable conditions of climate which weaken the vitality and vigor of the tree, encourage the presence and multiplication of the insect enemies. On the other hand, vigor of growth is repellent to insect attack; and it will be almost invariably found that the unhealthy tree is the one first severely infested with scale insects or mites. This does not mean that vigorous healthy trees will not be attacked, but such trees are less apt to be completely invaded. As a means of protection against scale insects, a proper system of cultivation and pruning is therefore highly important.

The value of pruning as a means of preventing scale-insect injury can not be too strongly urged. Scale insects thrive best where they are protected from direct sunlight and free movement of the air, hence trees of dense growth, unpruned, are almost certain to have their centers, at least, scaly. A well-pruned tree, in which free access is given to light and air, is much less apt to be badly attacked than a thick-headed tree, the interior of which is entirely shaded, thus furnishing the conditions most favorable for the well-being of scale insects.

The abundance or scarcity of scale-insect pests is very much influenced by climatic conditions. A moderate amount of moisture and warmth are the favoring conditions. On the other hand, a very dry climate accompanied during the summer season by excessive heat, will frequently destroy most scale pests, as will also a high degree of humidity with high temperature such as characterizes many areas within the Tropics, the latter condition developing fungous diseases which often keep most scale species well nigh exterminated. The favoring intermediate climate is illustrated by the citrus districts of Florida, Jamaica, and the West Indies, where scale enemies are more troublesome than they are in the drier climate of California. On the Pacific coast, also, the moister ocean districts are worse infested than the drier regions farther inland with greater elevation. Under the latter conditions the black scale, for example, has been almost entirely exterminated by a temperature holding for several days above a hundred degrees, and similar results have been noted with other species.

PERIODICITY IN SCALE INSECTS.

With most insects injurious to cultivated plants a periodicity is noted in their occurrence in injurious numbers. In the case of sub-tropical species, like the scale insects affecting citrus plants, this periodicity is not so marked as it is with insects in temperate latitudes. That there may be more or less well-defined periods of destructive abundance separated by periods of comparative scarcity is illustrated

by the noted epidemic of scale infection referred to by Hubbard as prevailing throughout the entire orange, lemon, and olive districts along the shores of the Mediterranean from Italy to Spain during the first decade of the present century, which later subsided very largely of itself, efficient remedies at that date being practically unknown.

In this country, scale infestation varies considerably from year to year. The fluted scale, in California, increased enormously during the first ten or fifteen years and threatened the very existence of the citrus orchards. Thanks, however, to the Australian ladybird, and, doubtless also to many native predaceous and parasitic insects, it is no longer feared in California. The long scale in Florida, also, was much more injurious in the first years of its activity than it has been since. In 1896 the black scale was very abundant and destructive in the orange districts about Riverside, Cal. Partly owing to adverse climatic conditions and partly to natural enemies, this insect has almost disappeared from this district, which is now one of the least affected by scale insects.

These facts are cited to give the citrus grower whatever encouragement they may offer, but not with the idea of belittling the need of remedial operations.

NATURE OF THE INJURY OCCASIONED BY SCALE INSECTS.

The damage occasioned by scale insects is of several kinds. The first and principal injury is the extraction of the juices of the plant, the scale insect in its relation to its food plant being a mere pumping machine, which is continually absorbing the sap from its host. While the amount extracted by a single insect is very small, when multiplied by millions it greatly weakens the plant. With some species the excess is thrown off in the form of so-called "honeydew," which accumulates in drops and spreads out over the bark or leaf as a sticky liquid. This liquid attracts ants, which very often gives rise to the erroneous belief that the ants are depredating on the plant.

Another form of injury results from the honeydew excretion, which not only prevents normal respiration, but develops a black fungus covering the leaves, twigs, and fruit, and still further stifling the plant and reducing the marketable value of its products.

Associated with the damage due to the absorption of the juices of the plant by the scale insect is a diseased condition, particularly to be noted in the limbs, caused by the irritation excited by the beaks or by the injection of some poisonous liquid.

The extreme injury by scale insects arises from the further fact that they are active the year round in climates where citrus trees can be grown. Their most rapid breeding period is from May to August, but continues through October and November. In the winter or rainy season they are more dormant and breeding is at a much lessened rate.

THE NATURAL ENEMIES OF THE CITRUS SCALE INSECTS.

The natural predaceous enemies of scale insects of greatest importance are various species of ladybirds, as illustrated by the Australian ladybirds (figs. 21 and 29) imported to control the fluted and black scales, and a great many native species, which are very effective agents in the control of these and other scale pests. The work of ladybirds is especially important against the young of the armored scale and against the softer and freely moving scale insects which secrete no protective covering. Whenever, therefore, ladybirds of any species are found to be abundant on scale-covered trees, they may be safely recognized as friends and working in the interest of the grower. If they are very abundant, it may even be unwise to fumigate or spray. The black scale has been completely controlled on certain ranches in California by its imported ladybird enemy, and this control has been brought about by the entire cessation of all insecticide operations. Most of our ladybirds, however, will probably stand a spraying without being killed, and, as a rule, it is hardly worth while to take the risk of loss while waiting for them to do their work. The experience, however, on the Cooper ranch and in other localities in California has certainly demonstrated the advantage of giving natural enemies a fair chance.

The other important class of enemies of scale insects are the hymenopterous parasites. The recognition of these is not so easy, but if scales are found pierced with minute round holes, it is a safe indication that they have been parasitized, and that the parasites have escaped and are multiplying in the younger scale insects on the trees, and here again if the parasitism is found to be general, it may be inadvisable to spray or fumigate.

The other natural enemies of scale insects are not so important as those mentioned; still they are of service, and should be recognized. These include the larvæ of the lace-winged flies (*Chrysopa* spp.), which feed on the young of both the armored and the unarmored scales. There are also a few dipterous, or fly, parasites of scale insects, and the larvæ of several species of Lepidoptera are carnivorous and feed on the larger species of scale insects, such as the Lecaniums and wax scales.

A most desirable outcome would be to secure a complete and practical control of scale insects by their natural enemies; but, so far, this has been fully accomplished in the case of the fluted scale only. Very encouraging results have been secured, however, with other parasites, and the introduction of these is being actively prosecuted. Nevertheless, spraying and fumigation must be relied upon for some time to come, or at least until the natural enemies have been more fully studied and better means of successfully colonizing them devised. Climatic conditions also affect the activity of these enemies to such an extent that the same results may not be counted on in different localities.

In considering the agency of control afforded by the natural enemies the fact must not be lost sight of that these are dependent on the scale insects for their existence, and that, therefore, a fairly complete extermination of the host insects means a like extermination of its enemies. There is, therefore, a natural alternation or periodicity in the abundance of the scale insect and its parasites. A more even balance may be maintained to a certain extent by artificial introduction of the parasitic insect the moment the scale has begun to be abundant, in this manner assisting the early multiplication of the natural enemy. This is now the practice with the fluted scale in California, South Africa, and Portugal. To succeed in such efforts, it is necessary to have an efficient parasite or predaceous insect, and also regular breeding places where these may be secured when wanted. These conditions may be naturally supplied when a whole district, such as California, is under constant observation and the localities where the parasite and scale are occurring together are known, so that from such points the ladybirds or other enemies may be collected and shipped to the districts needing them.

THE DIRECT MEANS OF CONTROLLING CITRUS SCALE INSECTS.

Scale insect enemies of citrus trees are directly controlled in two ways: (1) By spraying the infested plants with some liquid insecticide, (2) by subjecting them to the fumes of hydrocyanic-acid gas, commonly designated as "gassing." Each of these methods of control has its place.

THE GAS TREATMENT.

The gassing method (figs. 1-6) is undoubtedly the most effective means known of destroying scale insects. It has been in general use



FIG. 1.—Method of hoisting tent over orange tree.

in California for fifteen years, and to a less extent elsewhere on citrus trees, and the methods are now thoroughly perfected and highly satis-

factory. Gassing should undoubtedly be employed wherever the expense of the treatment, which is the one objection to it, is not an object as measured by the value of the crop protected. For most

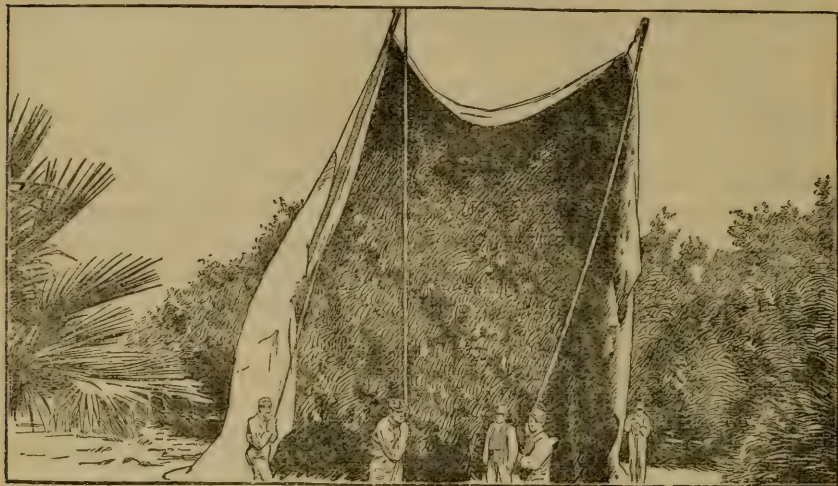


FIG. 2.—Tent carried over tree by the falling of pulleys.

species of scale insects, one good gassing is worth as much as two or three sprayings, and, when done at the right season and properly, it very frequently will almost, if not quite, exterminate the scale insects from the treated trees, giving them comparative immunity

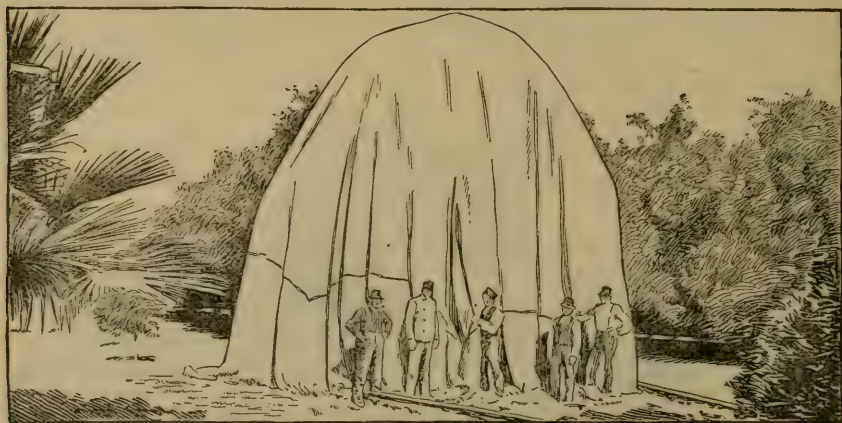


FIG. 3.—Tent in position for fumigation.

often for two or more years. The use of hydrocyanic-acid gas is, therefore, strongly urged wherever the conditions warrant it. Gassing is especially desirable for trees that have a dense habit of growth, such as the orange, which develops a large, thick head, the spraying

of which thoroughly and completely is almost impossible, especially after the trees have attained any size. Furthermore, with gas there is no danger of spotting the fruit as may happen with improper spraying.



FIG. 4.—Removing tent by horse power.

The more straggling growth of the lemon makes gassing less necessary, notably where the open system of pruning is adopted.

Successful as gassing is, it is not effective in the same degree against all the scale insect enemies of citrus plants. It is especially valuable



FIG. 5.—Series of tents for continuous operations.

against the black scale and the red scale of California, but with such of the armored scales as are oviparous, or deposit beneath the old scales eggs which undergo a certain amount of incubation before hatching, gassing is not always effective. Under such circumstances the

eggs may not be killed, rendering it necessary to make an additional treatment after a sufficient period has elapsed to allow all the eggs to hatch and the young to escape.

The black scale is especially adapted to control by gassing on account of its being, in the main, single-brooded. Applied late in October or early in November after all the young scales have hatched, badly infested orchards have been completely cleaned by a single treatment. Gassing in midsummer for this insect will be ineffective, because a large percentage of the old females at this period cover and protect unhatched eggs.

Gassing consists in inclosing a tree at night with a tent and filling the latter with the poisonous fumes generated by treating refined potassium cyanide (98 per cent strength) with commercial sulphuric

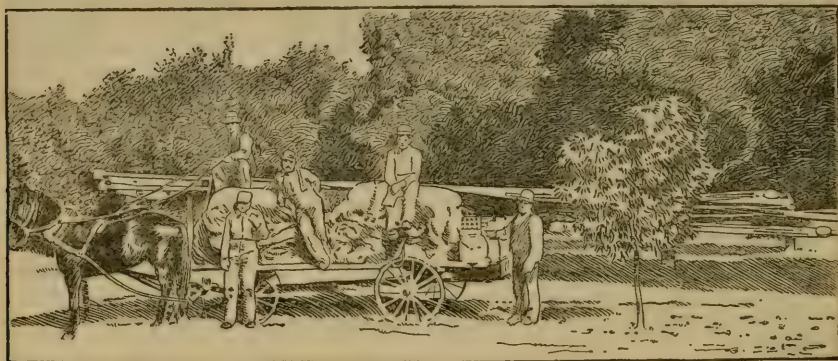


FIG. 6.—Tents, tackle, and chemicals loaded for transportation.

acid (66 per cent) and water. The treatment should continue from thirty to forty minutes, the longer time being preferable. The work is done at night to avoid the scalding which follows day applications, at least in bright sunlight.

The proportions of the chemicals as now employed in California are considerably in excess of the amounts recommended a few years since. The gas treatment was first chiefly used against the black scale, and at a season of the year when these scales were all in a young stage and easily killed. The effort is now made not only to kill the black scale, but also the red scale, and to do more effective work with both than formerly. The proportion of chemicals commonly employed in Los Angeles, Orange, and some other counties in southern California are indicated in the following table, published by the horticultural commissioners of Riverside County, Cal.:

Amounts of chemicals ordinarily used in gassing.

Height of tree.	Diameter through foliage.	Water.	Cyanide C. P. (98 per cent).	Sulphuric acid (66 per cent).
<i>Feet.</i>	<i>Feet.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>
6	4	2	1	1
8	6	3	1½	1½
10	8	5	2½	2½
12	14	11	5	5½
16	16	17	8	9
20	16-20	22	10	12
20-24	18-22	30	14	16
24-30	20-28	34	16	18
30-36	25-30	52	24	28

The amounts here recommended are thoroughly effective for the black scale at the proper season, and generally effective also for the California red scale and other armored scales. Where the treatment is designed to be absolutely one of extermination, and the expense is not considered, from one-third to one-half more of cyanide and acid is employed, as indicated in the table following, furnished by Mr. Felix G. Havens, of Riverside, Cal.

The greater expense entailed by this larger quantity of chemicals is offset by the more effective results and the longer intervals between treatments:

Excessive amounts used for extermination.^a

Height of tree.	Diameter through foliage.	Water.	Sulphuric acid (66 per cent.)	Cyanide C. P. (98 per cent).	Time to leave tent on tree.
<i>Feet.</i>	<i>Feet.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Ounces.</i>	<i>Minutes.</i>
6	3 to 4	3	1½	¾ to 1	20
8	5 to 6	6	2½	2	30
10	7 to 10	15	5 to 6	4 to 5	35
12	9 to 12	20 to 30	7 to 9	5½ to 7½	40
14	12 to 14	30 to 35	9 to 12	8 to 10	40
16	12 to 15	35 to 40	12 to 14	10 to 12	40
18	14 to 16	45 to 55	15 to 18	12 to 15	40 to 50
20	16 to 18	60 to 70	20 to 22	16 to 20	45 to 50
22	16 to 18	70 to 75	22 to 25	20	50
24	18 to 20	75 to 80	25 to 30	22 to 26	50
27	20 to 24	85 to 100	30 to 36	28 to 32	60
30	20 to 28	100 to 110	36 to 44	32 to 38	60

^a A fumigation of the orangery of the Department of Agriculture demonstrated that half an ounce of cyanide to the hundred cubic feet kills the eggs, even of the black, purple, and other scales. The results are scarcely comparable to the proportions recommended in the tables on this page, for the reason that in these tables the amount of cyanide is greatly lessened with larger trees, and furthermore, that the orangery probably retained the gas more effectually than would be the case with cloth tents. Nevertheless, it is interesting to know that a comparatively inconsiderable strength of cyanide, when applied under the best conditions, will prove thoroughly effective against the eggs as well as the insects.

For small trees ordinary earthenware vessels may be used to generate the gas. For large trees requiring heavy doses tall wooden pails have proved more practicable, two generators being employed for the very largest trees. It is important that the water be put in the vessel first, and then the acid, and lastly the cyanide. If the water and cyanide are put in the vessel first and the acid poured in afterwards there is danger of an explosion, which will scatter the acid and burn the tents and the operator. In the spring, when the trees are tender with new growth, and in early fall, when the oranges are nearly grown and the skins are liable to be easily marred, and also with young trees, it is advisable to add one-third more water than ordinarily used, or use the cyanide in larger lumps. This causes the gas to generate more slowly and with less heat, and if the tents are left over the trees a third longer the effectiveness of the treatment will not be lessened.

The extremely dangerous nature of the gas must be constantly borne in mind and the greatest caution should be taken to avoid inhaling it. The person handling the chemicals should always have an attendant with a lantern, to hold up the tent and enable the cyanide to be quickly dropped into the generator and to facilitate the prompt exit of the operator.

As with spraying, the gassing is often done (and this is very desirable also) by individuals or companies who make a regular business of it, charging a fixed rate per tree, depending on size—from 10 cents to a dollar or more. Much of this work is also done under the direct supervision of the county horticultural commissioners, which gives a greater assurance of efficiency.

Practically, the only tent now used is the so-called "sheet tent," which is drawn up over the tree by means of pulleys (figs. 1-3). For very large trees, averaging 30 feet in height, it is sometimes necessary to employ two sheets to effect a complete covering.

Some of the tents employed are of great size, the one illustrated in the figures, from photographs secured by Mr. Havens, having a diameter of 76 feet. As described by Mr. Havens, it is constructed of a central piece 50 feet square, of 10-ounce army duck. Four triangular sidepieces, or flaps, of 8-ounce duck, 10 feet wide in the middle, are strongly sewed to each side of the central sheet, forming an octagonal sheet 70 feet in diameter. About the whole sheet is then sewed a strip of 6-ounce duck, 1 yard wide. The tent is handled by means of ropes and pulleys. A $1\frac{1}{2}$ -inch manila rope is sewed about near the edge of the central piece in an octagonal pattern. Rings are attached to this rope at each of the eight corners thus formed, and also on opposite sides of the outer edge. To these rings the pulley ropes are fastened and the tent is elevated over the tree and handled as indicated in the plates.

The treatment is made altogether at night, although it would be

possible to treat trees also on a very dark or cloudy day. In California, however, at the time the gas treatment is made, such days are infrequent. About 50 trees of the largest size, 30 feet high or thereabouts, can be treated in a night with an equipment of twelve or fifteen tents (fig. 5). By the time the last tent is in place, the fumigation in the first is completed, and it can be taken down and moved forward, and so on with the others; thus the men at work handling the tents are kept continuously employed. Working in the same way with smaller trees, the number which can be treated in a single night is very considerable, it being possible to gas from 300 to 500 trees, averaging 10 feet in height, in eleven or twelve hours, employing 35 to 40 ring tents.

SPRAYS FOR CITRUS TREES.

It may often happen that gassing is impracticable or that the expense of the treatment is not warranted. This last may be the case where the rancher has not sufficient capital to keep up the heavy

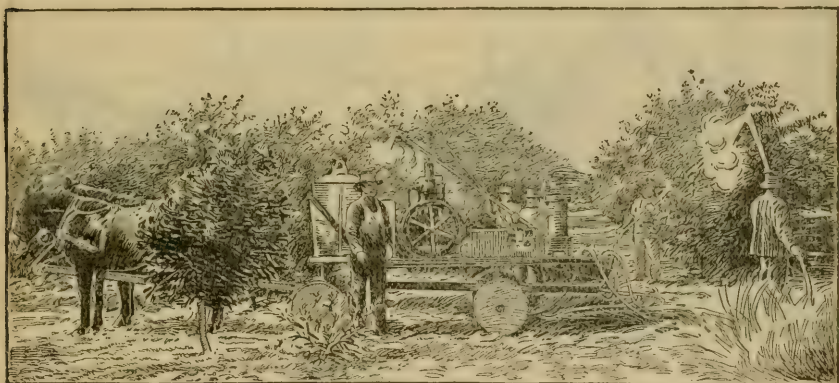


FIG. 7.—Gasoline-power spraying outfit with four lines of hose in operation.

outlay necessitated by the treatment of young stock which yields no revenue. Gassing is also difficult and less desirable where, as for the lemon in southern California, the low, open-center pruning is adopted, the trees under this system of pruning often having an expanse of 20 feet, with a height of scarcely more than 6 feet. This open system of pruning and more straggling form of growth, on the other hand, makes the lemon easier to treat with liquid sprays, and under such conditions spraying will probably prove more practicable and profitable than gassing. Nevertheless, where lemon trees are of a form and size to admit of it, and the crop warrants the expense, gassing is always to be recommended.

The expense of spraying is not heavy, compared with that of gassing. In most of the citrus districts of California where spraying is practiced to any extent there are individuals who make a business of treating orchards at a charge of a cent a gallon for the liquid applied, or about

double that price when they furnish as well as apply the insecticide. This work is now commonly done with a power apparatus (fig. 7),^a and usually in a fairly satisfactory manner. The difficulty in depending on the public sprayer is that it is very often not available when much needed. For a large ranch the possession of a power spraying outfit will probably prove economical in the long run, and anyone contemplating securing one is referred to the general article on such machines, by Dr. L. O. Howard, in the Yearbook of this Department for 1896.

For the small rancher, having from 10 to 30 acres of orchard, it is not necessary to go to the expense of a steam or a gasoline spraying apparatus. There are a great many excellent force pumps on the market which may be easily equipped with suitable hose and nozzles, and which will do the work of spraying very satisfactorily. A hand force pump with suitable connections, which may be equipped for



FIG. 8.—Hand-power spraying outfit with two lines of hose in operation.

work at a cost of from \$25 to \$30, will meet all requirements. The pump for such an outfit should be capable of easily producing a pressure of 100 pounds, which will supply four cyclone nozzles attached to two lines of hose. With such an apparatus (fig. 8), the writer was able to spray easily 50 gallons an hour, or 500 gallons a day, working with three men, and this covers also the time lost in mixing the insecticide and refilling. The cost of applying the same amount of liquid by a contract sprayer would probably be a little less, but under personal supervision, the work will undoubtedly be better done and with less waste of material, and, of more importance still, at the time when most needed and when the greatest advantage will result.

Trees under seven years old will probably require from half a gallon to a gallon of spray per tree. For an orchard of 10 acres, or about 860 trees, the cost of spraying would be about \$8 for the spray and

^aFrom photograph furnished by F. Kahles.

as much more for the labor. In other words, spraying with the insecticides commonly employed, such as "distillate," kerosene emulsion, and resin wash, may be safely estimated to cost about 2 cents a gallon for the amount of liquid used, or not exceeding 2 cents per individual tree under seven years of age. On the other hand, gassing trees seven years old will cost from 12 to 15 cents per tree, or the equivalent of from five to seven sprayings. The advantage, therefore, of spraying, for the small owner, and for trees especially suited by form of growth or pruning to such treatment, is evident.

The oily washes are by far the best for use on citrus trees against scale insects. The attempt has been made in various places to substitute lye washes for the old standard kerosene washes, but the effect has, as a rule, been disastrous. Lye strong enough to kill scale insects applied to a tree, as demonstrated by Hubbard fifteen years ago, is very destructive to the tender growth of the tree, and the damage from the wash is often greater than that occasioned by the insects themselves. In California, the kerosene and resin washes formerly used have now given place, to a considerable extent, to a modification of kerosene emulsion known as "distillate." As now employed, the washes in the order of their popularity are: (1) Distillate; (2) resin wash; (3) kerosene emulsion. The probability is that distillate will ultimately supplant the other two on account of its equal, if not greater, efficiency and smaller cost.

Distillate.—This wash was originated by Mr. F. Kahles, and has found very general use in the Santa Barbara region, and also in the lemon districts adjacent to San Diego, as well as in other citrus districts in California. It is substantially an emulsion of crude kerosene, made in the same way as kerosene emulsion, except that a greater amount of soap and only half as much oil are used. Its cheapness results from the latter fact. In spite of this lessening of oil it seems to be, if anything, stronger than kerosene emulsion.

It is termed distillate spray, because the oil used is a crude distillate of the heavy California petroleum, or the crude oil minus the lighter oils.

The emulsion or "cream," as it is generally known, is prepared as follows: Five gallons, "28° gravity," untreated distillate; 5 gallons water, boiling; 1½ pounds whale-oil soap. The soap is dissolved in the hot water, the distillate added, and the whole thoroughly emulsified by means of a power pump until a rather heavy, yellowish, creamy emulsion is produced. For use on lemon trees it is diluted with 12 parts of water, and with 15 parts of water for the orange. The "distillate cream" is prepared and sold by oil companies and private individuals at from 10 to 12 cents a gallon, making the dilute mixture, as applied to the trees, cost in the neighborhood of a cent a gallon.

Kerosene emulsion, made by the same companies, costs from 12 to 15 cents a gallon. In using these oil emulsions it is advisable to first break the water by the addition of a little lye, one-fourth pound being ample for 50 gallons of water.

Kerosene emulsion.—This wash, made according to the old formula (kerosene, 2 gallons; whale-oil soap, one-half pound; water, 1 gallon), is prepared in the same way as the distillate and used at the same strength. It does no harm to use double the quantity of soap indicated, securing in this manner a rather more stable emulsion. This emulsion, while perhaps somewhat less efficient than the distillate emulsion, is always available where the latter may not be in reach. It may be prepared on a small scale with an ordinary hand pump, but is best prepared in large quantities with a gasoline or steam-power pump to mix and emulsify it after the soap has been dissolved in the water by boiling.

The resin wash.—This wash is especially valuable against the California red scale. It may also be used against any other scale insect, including the black scale and the various armored scales affecting citrus trees. The wash is made as follows: Resin, 20 pounds; caustic soda (78 per cent), 5 pounds; fish oil, $2\frac{1}{2}$ pints; water to make 100 gallons. Ordinary commercial resin is used and the caustic soda is that put up for soap establishments in 200-pound drums. Smaller quantities may be obtained at soap factories, or the granulated caustic soda may be used, $3\frac{1}{2}$ pounds of the latter being the equivalent of 5 pounds of the former. Place these substances with the oil in a kettle with water to cover them to a depth of 3 or 4 inches. Boil about two hours, making occasional additions of water, or until the compound resembles very strong black coffee. Dilute to three times the final bulk with hot water, or with cold water added slowly over the fire, making a stock mixture to be diluted to the full extent as used. When sprayed the mixture should be perfectly fluid, and should any sediment appear the stock mixture should be reheated; in fact, the wash is preferably applied hot. This wash is more difficult to prepare than the emulsions referred to above, and is therefore much less employed.

CITRUS SCALE INSECTS: CLASSIFICATION AND CHARACTERISTICS.

For the purpose of this paper a very simple classification of citrus scale insects may be adopted, namely: (1) The armored scales, or those forming a protective covering scale and losing their limbs and the power of changing their situation as soon as they settle down to feed as newly hatched larvæ; (2) those species which secrete no covering shell or scale and retain their limbs and the power of moving about during most of their lives.

The species belonging to both groups are commonly called scale insects, although the term might seem properly to apply only to the

first group; nevertheless, the old insects in the second group, when they become hardened, and, in fact, the younger stages also, greatly resemble scales; hence, the name may properly apply to them as well.

These insects all belong to the family Coccidæ of the order Hemiptera, or true bugs, being allied to plant-lice and other suctorial insects of this order. In the larval stage the scale insects, except in point of size, closely resemble the larvæ of the higher forms of Hemiptera, and are active and can run about on plants or may be carried from one plant to another by the wind, or by birds or other insects to which they may attach themselves.

In the case of the armored scales, as soon as the young have undergone their first molt they appear as mere sacks provided with long sucking beaks, but without legs or eyes, and are very much degraded structurally from the larval condition. The unarmored scales, while retaining their limbs throughout life, are not apt to move very much after they have once settled and begun to feed, except in the case of one or two species. The power of locomotion, however, is retained, and in the case of the fluted scale and mealy bug is often actively brought into play; the Lecaniums and wax scales are apt to migrate late in their lives from the leaves to the twigs. The female insects of both groups remain on the plants and never advance to a winged stage. The males of both groups, however, while paralleling the development of the females in the early stages, in the later stages transform to pupæ, and eventually emerge as minute, two-winged gnats. The life of the winged male is very short, and its sole function is to fertilize the eggs of the female. It is a very delicate creature, having no mouth parts, but in place of them a second pair of prominent eyes.

GROUP 1.—THE ARMORED SCALES.

The majority of the important scale-insect enemies of the orange belong to the group known as armored scales because the insects begin to excrete as soon as they thrust their beaks into the tissues of the plant a waxy covering which protects the growing insect and forms a definite scale-like shield entirely independent of the insect itself. This group includes the long scale, purple scale, the red scale of California and the red scale of Florida (an entirely distinct insect), the oleander scale, the chaff scale, and other less important species.

In general habits these armored scales are very similar. The eggs, which are developed in enormous numbers, may be extruded under the covering scale of the mother insect and undergo a longer or shorter period of incubation before hatching, or the young may be partly or fully developed within the body of the mother and emerge as active insects, or more properly shake off the egg envelope at the moment of birth, so that certain species appear to yield living young. The young

of these different species of armored-scale insects very closely resemble each other, and can not be distinguished without careful microscopical study. While very minute, the young are yet visible to the naked eye, and during the breeding season may be seen, by sharp inspection, running about on the leaves, twigs, and fruit. In color they are usually light lemon-yellow. They have six well-developed legs, also antennæ and eyes, and are highly organized in comparison with the degraded condition soon to be assumed. After finding a suitable situation, often within a few minutes from the time of their emergence, though sometimes not for an hour or two, they settle down, thrust their long slender hair-like beaks into the plant, and immediately begin growth, the first evidence of which is the secretion of waxy filaments from the upper surface of the body, which mat down and form the beginning of the scale covering (fig. 12). This waxy secretion continues during the life of the insect, the covering scale being enlarged as the insect increases in size. The females undergo two molts, and the skins thrown off in these molts form a definite part of the scale, being cemented to it closely with the wax. The female insect, after the second molt, soon reaches full size, and when fertilized by the male begins to develop her numerous progeny.

The preliminary stages of the male scale insect exactly correspond with those of the female. After the first molt, however, the male assumes a slightly different appearance, being more elongate than the female at this stage. With the second molt the male diverges entirely from the female; the old skin is thrust out from beneath the covering scale, and does not become a part of it, as with the female, so that in the case of the male insect the first-shed skin only is associated with the scale, which never becomes more than one-half the size of that of the female. With this second molt the male insect transforms to a preliminary pupal stage, in which the antennæ, legs, and wings are partially developed. A third molt occurs with the male insect, resulting in the final pupal stage, which exhibits more fully formed legs and wings than the preceding stage and also the so-called terminal style. A fourth and last molt of the male produces the perfect insect, which escapes from beneath the covering scale and can fly about (fig. 11, *e*).

The periods between the moltings vary with different species and with weather conditions. Most of the species, however, reach full growth in from four to six weeks in summer; development is slower in winter.

The female insect, having once thrust her beak into the tissues of the plant as a larva and begun the secretion of a covering scale, never moves from her position; and, in fact, if she be removed by force is never again able to penetrate the bark with her sucking beak, and soon perishes. The opportunity for the local spread of these insects is, therefore, limited absolutely to the larval stage, as in this respect they

differ from the Lecaniums and mealy bugs, which have the power to move about until nearly the end of their growing period.

The number of eggs from a single female varies somewhat with the species, but may be from 100 to 500, the number being less in unfavorable seasons. The progeny from a single female in a year, if they should all survive, would represent almost inconceivable numbers, running into the billions. It is not to be wondered at, therefore, that plants become thoroughly infested with these insects in a very short time, especially in climates where the breeding is but little checked by the winter season.

The waxy covering makes it necessary to use rather strong washes to penetrate the scale. The difficulty increases when the old scale protects a mass of eggs, as is usually the case with the species of *Mytilaspis*, represented by the long and purple scales; and it is not always possible with the best washes to kill all the eggs of these species, hence the necessity of spraying repeatedly to destroy the young as they emerge. Remedial operations should be instituted as far as possible when the greatest percentage of the scales are in a young or partly mature condition.

The Long Scale.

The long scale (*Mytilaspis gloveri* Packard—fig. 9) is supposed to have originated in China, but in common with most of the other species discussed has now a world-wide distribution, being represented in practically every important citrus region.

It made its appearance in Florida about 1838, and soon became a very serious pest in that State and elsewhere in the Gulf region. At its first appearance it was vastly more destructive than later on, parasitic and natural enemies having in later years kept it decidedly in check. At present it is everywhere distributed throughout Florida and Louisiana, in the orange and lemon groves, and also on wild orange. Strangely enough, it was a long while getting into California. About 1889 or 1890, however, in company with the purple scale and rust mite, it was carried into California on a lot of stock from Florida, but it has not developed as a very serious pest in the Pacific coast region.

This insect is characterized by its very elongate form; in other respects it closely resembles *Mytilaspis citricola*, and also the common oyster-shell scale of the apple and other deciduous fruits. In color it

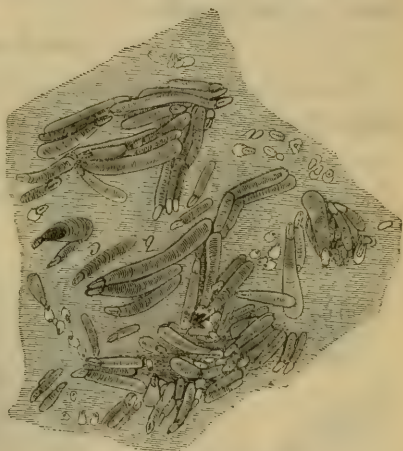


FIG. 9.—Long scale (*Mytilaspis gloveri*): Group figure, showing cluster of male and female scales on fruit of orange—enlarged 7 diameters (original).

is a rather rich reddish, often obscured by extraneous matter taken from the surface of the leaves or bark. It apparently requires a great deal of moisture to thrive well, and hence is apt to be abundant on oranges or other plants grown in conservatories, and this also accounts, doubtless, for its greater multiplication and injury in Florida than on the Pacific coast.

Breeding continues practically throughout the year. According to Hubbard, there are three periods in Florida when the young are especially abundant, marking in a rough way the appearance of the main broods, namely, in March and April, in June and July, and in September and October; the fourth, irregular brood, occurring in January or February.

The treatment for this scale is the use of the oily washes and fumigating with hydrocyanic-acid gas. It is much more easily controlled than the purple scale.

The Purple Scale.

The original home of the purple scale (*Mytilaspis citricola* Packard) (figs. 10 to 12) is unknown, but it now occurs practically wherever

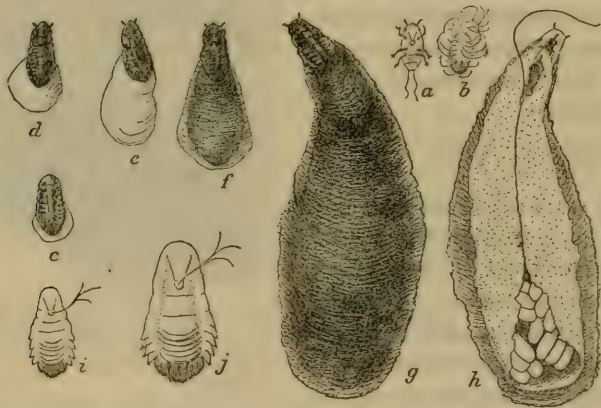


FIG. 10.—Purple scale (*Mytilaspis citricola*), showing different stages of female: *a*, newly hatched larva; *b*, same with first waxy secretion; *c* to *f*, different stages of growth; *g*, mature scale; *h*, same inverted, showing eggs; *i* and *j*, half-grown and full-grown female insects removed from scale—all much enlarged (original).

the orange or lemon is grown. It was probably introduced into this country at an early date. It is frequently associated with the long scale, and is one of the most troublesome scale insects affecting the orange and lemon, because it is very difficult to get an application on the trees strong enough to kill all of its eggs with one treatment. For many years the purple scale was limited in this country to Florida and the Gulf region, but some years since it was carried on Florida stock into southern California, where, fortunately, it has not yet become widely distributed. In general color it is a brownish purple, and in shape duplicates the oyster-shell scale of the apple. The life

history and habits are the same as those of the long scale. The purple scale is not limited to citrus fruits, but occurs also on many other plants.

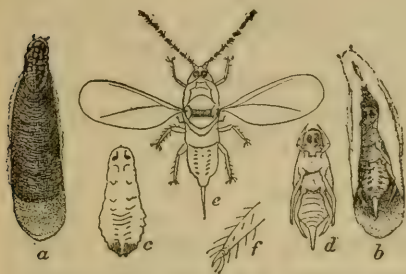


FIG. 11.—Purple scale (*Mytilaspis citricola*), showing different stages of male: a, fully developed male scale; b, same inverted, showing male pupa within; c, propupa; d, final pupal stage; e, mature winged insect; f, foot of same much enlarged—all greatly enlarged (original).



FIG. 12.—Purple scale (*Mytilaspis citricola*), illustrating the formation of the scale covering: a, newly hatched young, with enlarged antennae at left and leg at right; b, side view of forming scale; c, same from above—all greatly enlarged (original).

Neither the gas treatment nor any of the washes is a certain remedy for this scale, except in the immature stages. Occasionally a very strong treatment will kill the eggs, but it is usually necessary to repeat the application once or twice at intervals of two or three weeks to effect anything like extermination.

The Red Scale of Florida.

This is another scale insect (*Aspidiotus ficus* Ashmead) of world-wide distribution. As an orange scale it is not a very serious pest on trees grown out of doors, but on trees grown in conservatories or under glass it is very apt to thickly infest the leaves and fruit. It has a very wide range of food plants and



FIG. 13.—Florida red scale (*Aspidiotus ficus*): a, leaves covered with the male and female scales—natural size; b, newly hatched insect with enlargements of antennae and leg; c, d, e, f, different stages in the development of the female insect, drawn to the same scale; g, adult male scale—similarly enlarged (original).

is one of the commonest of scale insects. This and the following species differ from the *Mytilaspis* scales in being nearly circular in general outline, with the molted skins in the center of the scale instead of at the small end (fig. 13). The color of this scale is a rich reddish

brown, almost black. The central portion, however, is much lighter, giving the appearance of a dark ring with a light center. The number of generations can not be accurately given, breeding going on throughout the year, but undoubtedly in greenhouses and tropical regions six or seven generations are not unusual, and in subtropical regions five generations may be safely counted. It seems never to have attracted any attention as an enemy in the orange and lemon groves of California, the dry climate evidently not suiting it. The moist climate of Florida and the Gulf region seems more favorable to it.

The Red Scale of California.

This species (*Aspidiotus aurantii* Maskell) (fig. 14) is entirely distinct from the red scale of Florida. Its name comes not from the covering scale, as with the Florida species, but from the fact that the body of the mature female turns a reddish brown and shows through the thin

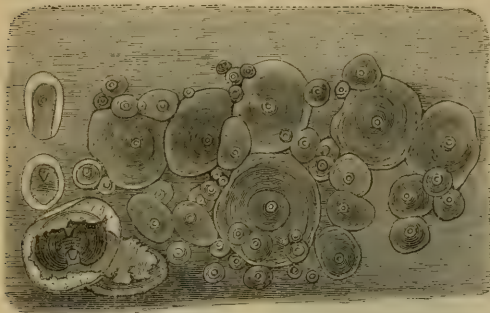


FIG. 14.—California red scale (*Aspidiotus aurantii*), illustrating a group of the female and male scales as they occur on an orange leaf—enlarged about 7 diameters (original).

transparent waxy scale. This insect, although for years very common and destructive in the groves of southern California, and enjoying also a cosmopolitan distribution, has, curiously enough, never appeared in a destructive way elsewhere in this country. Its origin is a matter of some uncertainty. It is now widely distributed, and has undoubtedly been a scale

pest in oriental countries for centuries. It is not limited to citrus plants, but may occur on almost any plant growing in tropical or subtropical regions. It is the most destructive and injurious of all the scale insects affecting the orange in California, being especially troublesome in the districts about Los Angeles. So far no effective parasites or predaceous insects have been found to combat it. It is controlled by the oily washes, and also by the gas treatment. The young are born free, or, in other words, the insect is semi-oviparous, and therefore any wash which will kill the old scale will destroy the young also.

This insect has, in California, a rather well-marked variety, known as the yellow scale (*Aspidiotus citrinus* Coq.). This variety does not differ in any structural feature from the red scale, but the mature insect remains yellowish in color. This variety is attacked by quite a number of parasitic flies, which keep it more or less in check, so that it is not, as a rule, so abundant as the red variety.

The Oleander Scale.

This species (*Aspidiotus hederæ* Val.) is not distinctively an orange pest. It occurs on a great variety of plants and has a world-wide distribution. It occasionally occurs on the lemon and orange, especially in California, not apparently being so likely to attack this plant in Florida. It is a very delicate scale, with a very thin waxy covering, and yields readily to treatment. It frequently occurs on the oleander, and is commonly known as the oleander scale (fig. 15). The male scales are white and very greatly exceed the females in abundance (much more so than indicated in the accompanying illustration). The female scales are light buff in color with a faint purple tinge, rather than white, are two or three times the size of the male scales, and rather larger also than the scales of the species already described. The fruit of the lemon and orange is often invaded by the females of this species.

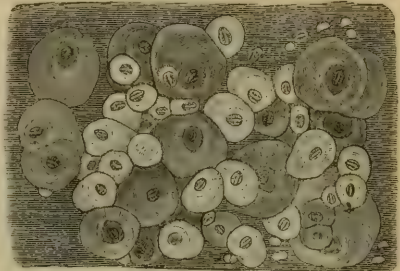


FIG. 15.—Oleander scale (*Aspidiotus hederæ*), illustrating a group of the female and male scales as they occur on a leaf—enlarged about 7 diameters (original).

The Chaff Scale.

With this scale insect (*Parlatoria pergandei* Comstock) the molted skins are at one end of the scale, as in the case of *Mytilaspis*, and the scale is oval or nearly circular, as in the case of *Aspidiotus*. It is very apt to be clustered thickly, often overlapping on leaves or twigs and fruit, giving the surface a rough appearance, as though covered with loose chaff (fig. 16). In color the female scale is light straw-yellow, the female insect showing through, usually with a greenish tinge. The number of generations and life history correspond very closely with the species already described. As a rule, the chaff scale by preference remains on the trunk and branches, covering these portions of the plant densely before going on the leaves and fruit. This fact renders it somewhat less noticeable than the other species, and its presence may, for a time, be overlooked.

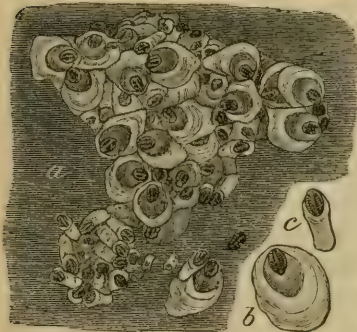


FIG. 16.—Chaff scale (*Parlatoria pergandei*), illustrating a group of the female and male scales as they occur on a leaf—enlarged about 7 diameters (original).

The chaff scale has been destructive, so far, only in Florida and the Gulf region, having apparently been introduced from the Bermuda

Islands or some of the West Indies. It is closely allied to certain scale insects occurring in the Old World, and probably came to this country from Europe or Asia. It yields to the same treatments which are advised for the other armored scales.

The Orange Chionaspis.

This species (*Chionaspis citri* Comstock) occurs in the orange groves of the Eastern United States, and is also especially troublesome in Louisiana. Professor Morgan reports that its presence on the



FIG. 17.—Orange Chionaspis (*Chionaspis citri*), illustrating a group of the female and male scales as they occur on a leaf—enlarged about 7 diameters (original).

trees causes a bursting of the bark and very ugly wounds, followed in very many cases by the rotting of the trunks of the older trees. The orange Chionaspis (fig. 17) is found also in several of the West Indian islands, Mexico, and in most foreign countries where citrus fruits are grown. The male scales are striking objects on account of their white color, and the females are readily distinguished from the other armored scales of similar general shape by the dis-

tinctly ridged appearance of the waxy portion. The orange Chionaspis is readily controlled by the same treatments advised for the other armored scales.

GROUP 2.—THE UNARMORED SCALES.

The species to be considered in this group include three Lecaniums, the mealy bug, two wax scales, and the fluted scale. Strictly speaking, the Lecaniums are the only ones which secrete no covering. The mealy bug secretes a waxy or mealy powder, which covers its body, and a similar secretion in less amount is made by the fluted scale. Both of the latter species secrete very abundant quantities of wax for the protection of their eggs. The wax scales cover themselves with copious waxy secretion, which, however, attaches firmly to the body, and can not be considered as a separate covering in the sense of the scale of the armored species. The development of the different species in this group is very similar, in that they all retain the power of locomotion until nearly the end of their lives, and do not suffer the loss of limbs and the marked retrograde development already described in the case of the armored scales. They excrete liberally the honeydew, which is followed by the smut fungus. In this group are included some of the worst scale pests of the orange and lemon, notably the black scale, the fluted scale, and the mealy bug. Not being so firmly attached nor

so protected by a covering shell or scale, they are as a rule more easily destroyed by fumigation or sprays, and they fall a more ready prey to attacks of predaceous and parasitic insects. All of the species are egg-laying. The Lecaniums and wax scales deposit their eggs in cavities under their bodies, formed by the contraction of the female insects, so that ultimately the mothers become mere shells over vast numbers of eggs and hatching young. The mealy bugs and fluted scale excrete a quantity of cottony fibers, which are stocked with eggs. After a certain amount of incubation, the young hatch and escape from beneath the old parent scales or burrow out of their cottony nests. In transformations and general life history, except in the points noted, these scale insects closely duplicate the habits of the armored scales.

The Black Scale.

This scale insect (*Lecanium oleæ* Bernard—figs. 18, 19, and 20) is notably an olive pest, but it also attacks citrus fruits, and is quite as destructive to the latter as to the olive. It is an insect of world-wide distribution, having been an important enemy of the olive and citrus fruits in the Old World as far back as we have any records. It also affects a great variety of other fruits and plants. It occurs more or less in greenhouses, and has undoubtedly been transported to various parts of the world upon greenhouse plants as well as upon the various subtropical fruits. In the United States it is especially destructive only on the Pacific coast, and while it occurs generally in Florida it has never there assumed any great importance as an enemy of the orange or lemon. It not only saps the vitality of the plants by the extraction of their juices, but also abundantly secretes honeydew, which results in a badly attacked plant becoming thoroughly coated and blackened with the sooty fungus.

The adult insect is dark brown, nearly black, in color. Its characteristic features are the one longitudinal and the two transverse ridges. Very often the portion of the longitudinal ridge between the two transverse ridges is more prominent than elsewhere, giving a resemblance in these ridges to a capital letter H. The general surface of the body of this scale insect is shagreened or roughened, which will distinguish it readily, under a hand lens, from the allied species, even before the ridges have become prominent. Very fortunately for the citrus grower, the development of this insect is slow, and it has but one brood annually. The young, however, appear over a very wide interval of time, and this gives the appearance of more than one brood.

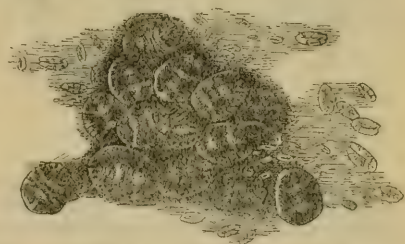


FIG. 18.—Black scale (*Lecanium oleæ*): Group of scales, showing natural position and appearance—enlarged 4 diameters (original).

On reaching full growth, early in the summer, the female insect deposits her eggs beneath her already much-hardened parchment-like skin, the lower surface of the body gradually contracting until there is nothing left but the shell, covering a mass of hundreds of eggs. The eggs will hatch in a comparatively short time, but, as the females come to maturity at different dates, the young from this species are constantly appearing and spreading over the infested plants between June and the end of October. The growth, however, is very slow, and even those earliest hatched do not reach maturity until late in autumn, the latest maturing in June and July of the following year.

While retaining the power of movement practically throughout its development, this scale insect is very little apt to change its position

after it is once settled, or, at least, after it is half grown. There is a general migration from leaf to twig, but the scale often develops

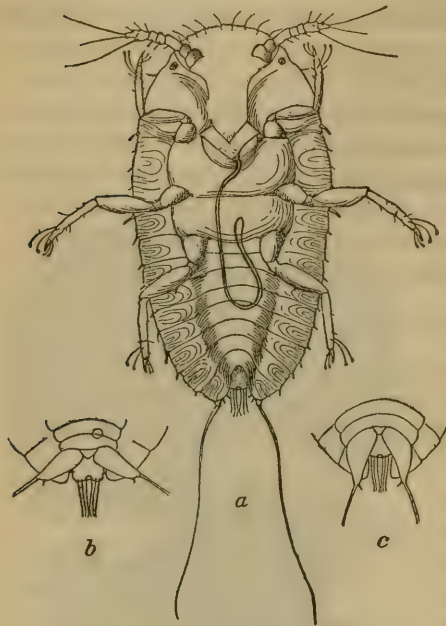


FIG. 19.—Black scale (*Lecanium oleæ*): a, greatly enlarged drawing of newly hatched larva, viewed from beneath, with enlargements of anal extremity viewed from above—b, showing anal segment extruded, and c, same retracted (original).

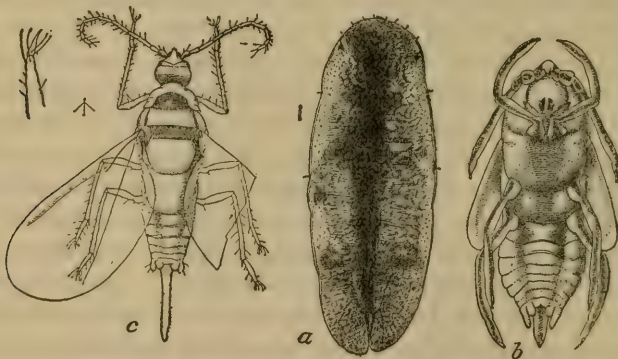


FIG. 20.—Black scale (*Lecanium oleæ*), male series: a, fully developed male scale; b, pupa; c, winged adult—natural size indicated by hair lines (original).

on the leaf if the latter remains vigorous and supplies it sufficient nourishment.

In view of the extraordinary abundance of the black scale it is surprising that until very recently the male insect had not been discovered, in spite of the most careful search for it. What we know of this stage is due to Dr. B. W. Griffith, of Los Angeles, Cal., who has found the male scales on oleander, orange, lemon, pepper, and ivy leaves between the months of November and April, in Los Angeles County. The accompanying illustrations of this sex (fig. 20) are based on material furnished by Dr. Griffith.

The natural enemies of the black scale promise to be very efficient in its general control and warrant special notice. They include both the parasitic flies and various species of ladybirds.



FIG. 21.—Imported ladybird enemy of black scale (*Rhizobius ventralis*): a, mature beetle; b, larva—both greatly enlarged (author's illustration).

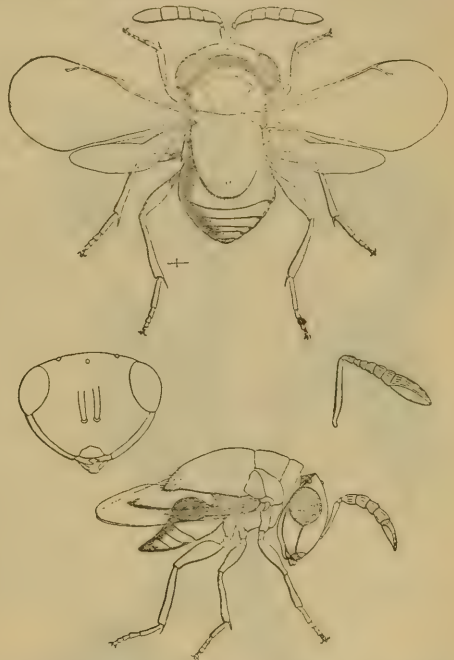


FIG. 22.—Imported chalcidid parasite of black scale (*Scutellista cyanea*), dorsal and lateral views—greatly enlarged (after Howard).

The ladybird enemy of special importance is the *Rhizobius ventralis*, imported by Mr. Koebele. This ladybird (fig. 21) has been colonized in various parts of California, and in districts where the climatic conditions proved favorable its work has been most satisfactory, notably on the ranch of Hon. Ellwood Cooper, at Santa Barbara. Hundreds of thousands of these beetles have been distributed in southern California and have accomplished in some localities a very great deal of good in keeping the black scale in check. Away from the moist coast regions, however, it is less effective, and experience has shown that this ladybird can not be completely relied upon to control the black scale.

A parasite which promises to be most effective in controlling the black scale is the very odd-shaped little chalcidid fly (fig. 22) known as *Scutellista cyanea* Motsch., first found attacking *Lecanium coffeae* in Ceylon. It was later reported by Dr. Berlese as attacking a wax scale (*Ceroplastes rusci*) in Italy. Subsequent to its discovery in Italy, various efforts were made by Dr. Howard, with the assistance of Dr. Berlese, to introduce it into Florida and the Gulf districts, particularly as a means of controlling the wax scales. In the meanwhile it was found with the black scale in Cape Colony by Mr. Lounsbury, who, at Dr. Howard's suggestion and with his assistance and the cooperation of different persons in California, notably Mr. Craw and Mr. Ehrhorn, succeeded, in 1900, in getting the parasite into California, where it has been installed under conditions which promise a successful introduction of the species. During the last three years it has been constantly distributed in California

and reports of its work are most favorable. In South Africa, as reported by Mr. Lounsbury, the black scale very rarely is abundant enough to be considered at all injurious, and this is apparently due to its parasitism by this little insect. If the latter can be induced to play the same rôle in California the saving will be second only to that accomplished by the *Vedalia*.

The remedial measures for the black scale are spraying with the oily emulsions and the gas treatment.

The Soft Scale.

This scale insect (*Lecanium hesperidum* L.—fig. 23), also known as the turtle-back scale or brown scale, is closely related to the black scale, but is a much softer and more delicate insect. It changes in color with age



FIG. 23.—Soft scale (*Lecanium hesperidum*): Orange twig showing characteristic massing of the scales—natural size (after Comstock).

from a transparent yellow in the young to deepening shades of brown in the adult. The adult scale has a length of 3 or 4 millimeters, is turtle-shaped, and very much swollen, the body of the mother in the last stages becoming a mere cap filled with young. In the early stages the insect is thin and flat and semitransparent, so

that it is scarcely noticeable on the surface of the leaf or twig. It is very commonly found on various greenhouse plants, and has been carried to all parts of the world on such material. In climates suitable for the growth of the orange and lemon it occasionally gains a foothold on outdoor plants. It has a gregarious habit, and commonly lives in colonies, frequently covering the young limbs and the midribs of the leaves. These colonies are usually not of long duration, being soon attacked and exterminated by parasitic and predaceous enemies, the soft texture of the insect not furnishing much, if any, protection. The transformation and habits are very similar to those of the black scale. It, however, is much more rapid in growth, and, where the climate is favorable, goes through a continuous series of generations, or broods, throughout the season. It readily yields to oily washes or to the gas treatment.

The Hemispherical Scale.

This scale (*Lecanium hemisphaericum* Targ.—fig. 24) is also distinctively a greenhouse pest, and it can hardly be considered as especially injurious to citrus trees in orchards. It occurs all over the world, and occasionally will multiply to a slight extent on orchard trees. The individuals are about the same size as those of the last two species. In color it ranges from light brown in the young to dark brown, changing to reddish in the old scale. The adult scale is hemispherical in shape perfectly smooth and shiny, and this, with its color, readily distinguishes it from the other two species. The remedies are those used against the black scale.



FIG. 24.—Hemispherical scale (*Lecanium hemisphaericum*): a, characteristic group of adult scales on olive—natural size; b, three female scales—considerably enlarged; c, scale lifted from leaf, showing mass of eggs (original).

The Florida Wax Scale.

This very curious and striking scale insect (*Ceroplastes floridensis* Comstock) secretes a white waxy covering, arranged in a very regular geometrical pattern (fig. 25). It was long known from Florida, where it is undoubtedly native, its principal food plant being the gall berry. It has now been carried, however, to other parts of the world, notably some of the adjacent West Indian islands, and also to the Old World. It was imported into California on stock from Florida in 1889, and possibly earlier, but has never gained any foothold on the Pacific coast. This insect often occurs on citrus plants, though rarely in sufficient numbers to be of very great importance. The white color and striking appearance of these scales cause them often to be noted,

and very natural fears of damage are excited, but as a rule the natural enemies and other causes result in very few of the young reaching the adult stage. This, as shown by Mr. Hubbard, not only follows the action of parasites, but also is due to the fact that the scale lice as they

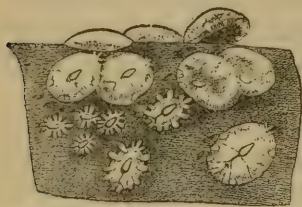


FIG. 25.—Florida wax scale (*Ceroplastes floridensis*): Group of scales, illustrating different stages of growth—enlarged about 4 diameters (original).

become old and gravid can not maintain their hold on the smooth surface of the lemon or orange leaf and fall to the ground and perish. The citrus plants, therefore, are not especially adapted to this insect and very rarely suffer long or seriously from it.

The Florida wax scale is three-brooded, development not being very rapid and extending over three or four months. The waxy secretions give an appearance to the young insect of an oval stellate object, the waxy prominences coalescing and disappearing with age.

The Barnacle Scale.

This insect (*Ceroplastes cirripediformis* Comstock—fig. 26), which is closely allied to the last, has been found in two or three localities in Florida, notably at Jacksonville and in Volusia County, on orange and quince, and also on a species of *Eupatorium*. It is frequently associated on citrus plants with the Florida wax scale. It has since been found on the same and other food plants on some of the West Indian islands and in Louisiana and California. The barnacle scale is much larger than the Florida wax scale, having an average length of 5 millimeters and a width of 4 millimeters. The waxy covering is a dirty white, mottled with several shades of grayish or light brown, and the division of the waxy excretion into plates is distinct, even to a late age. The development of the insect and secretion of the waxy scale covering is very similar to that of the last species described. The barnacle scale is of very little economic importance, and is mentioned merely because its presence might arouse suspicions of probable injury.



FIG. 26.—Barnacle scale (*Ceroplastes cirripediformis*): Group of scales on twig, illustrating different stages of growth—enlarged about 2 diameters (original).

The Fluted Scale.

Of all the scale insects attacking citrus plants, this species (*Icerya purchasi* Maskell—figs. 27 and 28) is perhaps the most notable, not so much from the damage now occasioned by it as from the problems of control which it has brought to the front and the international character of the work which it has occasioned.

The facts indicate that Australia is undoubtedly its original home, from whence it was introduced on Australian plants into New Zealand, Cape Town, South Africa, and California at about the same time. The evidence points to its introduction into California about the year 1868 on *Acacia latifolia*. It is a very hardy insect, will live for some time without food, and thrives on a great number of food plants. In California it spread rather rapidly, and by 1886 had become the most destructive of orange scale pests. The damage occasioned by it was of such a serious character as to threaten the entire citrus industry of the Pacific coast. The nature and habits of this insect made it almost impervious to any insecticide washes, and the orange growers of California were rapidly losing heart.

In 1889, however, through the agency of Mr. Albert Koebele, an assistant of this office, the natural ladybird enemy of the fluted scale was discovered in Australia and imported into California. This ladybird, *Novius (Vedalia) cardinalis* (fig. 29), multiplied prodigiously, and in a very short time practically exterminated the fluted scale, saved the State of California annual damage amounting

to hundreds of thousands of dollars, and removed this scale insect from the roll of dreaded injurious species.

The beneficial results derived from this ladybird have not been confined to California. Through the agency of this Department and in cooperation with the California State authorities, this ladybird has been sent to South Africa, Egypt, Portugal, and Italy, and in each of these countries its introduction has been followed by similar beneficial results in the control of the fluted scale.

While the fluted scale, at the time or soon after its injurious record in California, gained access to several foreign countries, very fortunately Florida and the Gulf districts remained long free from it.

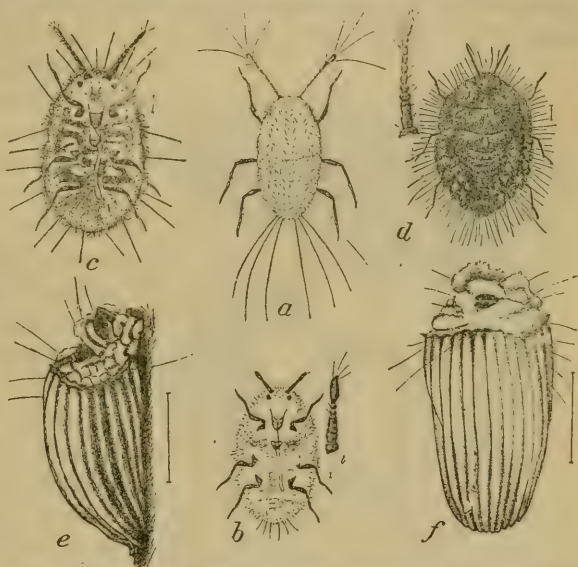


FIG. 27.—Fluted scale (*Icerya purchasi*), female series, illustrating the development of the female insect from young larva to adult gravid stage: *a*, newly hatched larva; *b*, second stage; *c*, third stage; *d*, full-grown female; *e* and *f*, same after secretion of egg sac—(original and after Riley).

The first and presumably only introduction of this insect into Florida was an intentional one, though not malicious, and illustrates the risk run in importations of beneficial insects undertaken by persons unfamiliar with the subject. A nurseryman of Hillsboro County, Fla., hoping to duplicate against the common Florida scale insects the wonderful work of the imported Australian ladybird against the fluted scale in California and, ignorant of the fact that the ladybird in question did not feed on any of the armored scales which he especially wished to have controlled by it, got one of the county horticultural commissioners of California to ship him a lot of these ladybirds, together with some of the fluted scale as food. The whole lot was liberated on his premises and resulted, naturally enough, in stocking some of his trees very thoroughly with the fluted scale. The infestation

coming to his attention, he sent, in June, 1894, specimens to the Division of Entomology and they were promptly determined as the dreaded California scale pest. Fortunately, the nurseryman in question realized the enormity of his offense and took, at Dr. Howard's earnest suggestion, immediate and active measures to exterminate the fluted scale on his premises, ultimately taking out and burning the trees.

It was hoped that extermination had been effected, but four years later (1898) the fluted scale was again received from the same district. In view of its quite general

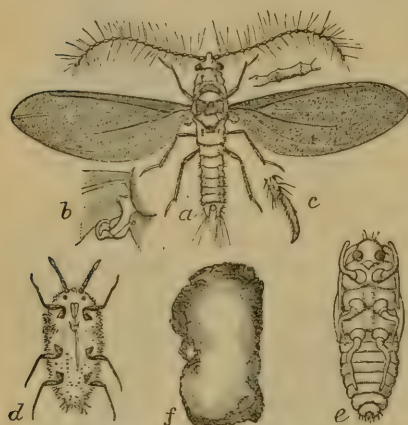


FIG. 28.—Fluted scale (*Icerya purchasi*), male series: a, male insect with greater enlargements of base of wing and foot at b and c; d, second stage of larva; e, pupa; f, cocoon—enlarged about 7 diameters (re-engraved from Riley).

spread, as reported, in the immediate region, it seemed improbable that it could be easily exterminated, and the introduction of the Australian ladybird was urgently advised. During the spring and summer of 1899 the ladybird in question was successfully colonized in Florida by Mr. Gossard, with the assistance of Mr. Craw.

The fluted scale in Florida evidently does not multiply as rapidly as it does in California. Furthermore, as shown by Mr. Gossard, it is attacked by a fungous disease which appears suddenly in July and results in the death of from 25 to 70 per cent of the partly grown scales. We may hope that with the aid of this disease, and by means of the prompt introduction of its natural enemy, the fluted scale will never play the rôle in Florida which it originally did in California.

The habits and transformations of the fluted scale (figs. 27 and 28) closely parallel those of the species of *Lecanium* already described.

The general appearance of the insect, however, is strikingly dissimilar, owing to the waxy excretions from the ventral plate of the adult female insect. These are ribbed, or fluted, from whence the insect takes its name, and become the receptacle of a vast number of eggs, a single female being the possible parent of more than a thousand young. The waxy material constituting the egg sac issues from countless pores on the under side of the body, especially along the posterior and lateral edges. As this secretion accumulates the body is lifted, so that ultimately the insect appears to be standing almost on its head, or nearly at right angles to the bark. The eggs are laid in the waxy secretion as it is formed, the waxy fluted mass often becoming from two to two and one-half times as long as the insect itself. The young are of reddish color, very active, and spread by their own efforts and by the agency of the winds, birds, and other insects. The female insect is, for the most part, a reddish orange, more or less spotted with white or lemon.

The early stages of the male are similar to the corresponding stages of the female. Before appearing as an adult, the male insect secretes itself in some crack in the bark, or in the ground, and exudes a waxy covering, which forms a sort of cocoon, in which the transformations are undergone, first into the pupa and then into the adult insect. The winged male (fig. 28) is rather large for a coccid, and has a reddish body with smoky wings.

The rate of growth of the fluted scale is comparatively slow, and it does not normally have more than three generations annually. This insect is quite active, the female traveling and moving about very freely nearly up to the time when she finally settles for egg-laying. The male is active up to the time when it settles down to make its cocoon.

The fluted scale exudes a great quantity of honeydew, and trees badly attacked by it are covered with the sooty fungus, characteristic of the black scale and the white fly.

The remedy for this scale insect is always and emphatically to secure at once its natural and efficient enemy, the *Novius cardinalis*. Where this insect can not readily be secured, the scale may be kept in check by

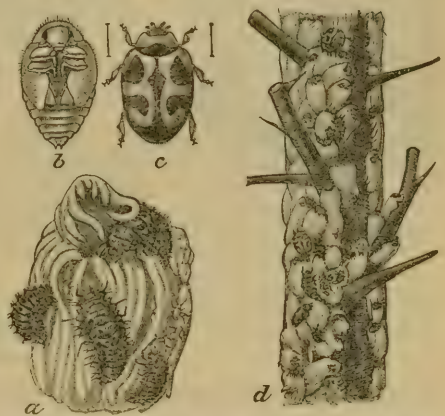


FIG. 29.—*Novius cardinalis*, Australian ladybird enemy of the fluted scale: a, ladybird larvæ feeding on adult female and egg sac; b, pupa; c, adult ladybird; d, orange twig, showing scale and ladybirds—natural size (author's illustration).

frequent sprayings with the kerosene or resin washes. Fumigation is comparatively ineffective against it, because the eggs are not destroyed by this treatment. Spraying is, for the same reason, effective only when it is repeated sufficiently often to destroy the young as they hatch.

The Mealy Bug.

The mealy bug (*Dactylopius citri* Risso) (fig. 30) of the orange and other citrus plants is especially destructive in Florida and the West Indies. It is not of much importance in California.

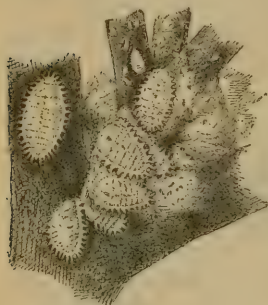


FIG. 30.—Mealy bug (*Dactylopius citri*): Mass of insects at fork of leaf, showing different stages and cottony excretion covering eggs—enlarged 4 diameters (original).

It occurs very commonly in greenhouses, and has been carried to every quarter of the globe. The insect is mealy white in color, the female attaining a length of nearly a quarter of an inch when fully adult. The edge of the body is surrounded by a large number of short waxy filaments. This insect is active in all stages and the eggs are laid in and protected by a cottony or waxy secretion, the female insect as this is developed being gradually forced from the bark, as in the case of the fluted scale. The adult winged male is light olive brown.

This species is somewhat gregarious and occurs in masses in the angles of the branches and leaf petioles and about the stem of the fruit. The remedies are the emulsions and oily washes, repeated as often as necessary to reach the young as they hatch.

IMPORTANT CITRUS PESTS OTHER THAN SCALE INSECTS.

THE WHITE FLY.

The white fly (*Aleyrodes citri* Riley and Howard) of Florida and the Gulf region (figs. 31 and 32) is not a scale insect, but belongs to a closely allied family. In general appearance and habits, however, at least in its economic features, it exactly duplicates the true scale insects. For many years this very interesting insect has been known to infest the orange trees of Florida and Louisiana and also to be a common pest on the orange in greenhouses. It has been found also on a number of plants other than orange, such as viburnum, cape jasmine, and the aquatic oak of the South. These other food plants are of significance only in indicating that it may be harbored in situations near orchards in which efforts have been made to exterminate it. The first careful description of this insect and general account of its habits was given by Riley and Howard in 1893, and from their article the data following are largely derived.

The white fly is limited, economically, to the citrus plantings of Florida and the Gulf region. It is widely distributed in greenhouses, as already noted, and has undoubtedly been carried to California on many occasions, but has never gained a foothold out-of-doors. The dry hot season of southern California probably accounts for this, and may prevent its ever becoming troublesome in that region. Its origin is unknown. It first came into prominence about 1885, but probably had been present in greater or less numbers for a much longer period, and perhaps is native to Florida.

While closely resembling a scale insect in its early stages, the white fly in the adult stage emerges, in both sexes, as a minute white gnat, having four chalky wings of a fine glandular texture, from which fact it is frequently called the "mealy wing." This active adult condition gives the white fly a distinct advantage over scale insects in means of spread.

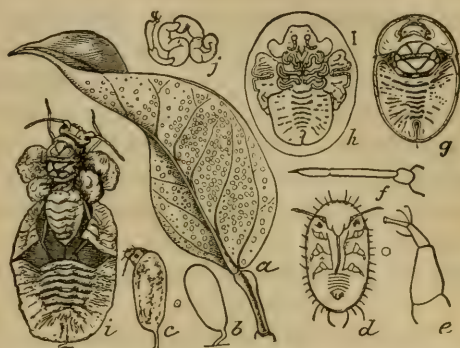


FIG. 31.—White fly (*Aleyrodes citri*): a, orange leaf, showing infestation on under surface—natural size; b, egg; c, same, with young insect emerging; d, larval insect; e, foot of same; f, larval antennae; g, scale-like pupa; h, pupa about to disclose adult insect; i, insect escaping from pupal shell; j, leg of newly emerged insect, not yet straightened and hardened—all figures except a greatly enlarged (reengraved from Riley and Howard).

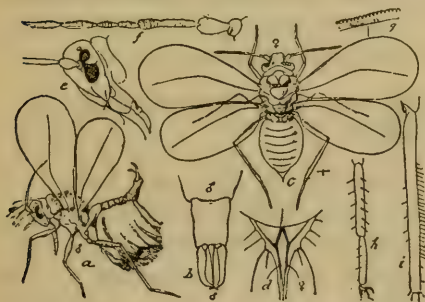


FIG. 32.—White fly (*Aleyrodes citri*): a, winged male insect, with enlarged view of terminal segments at b; c, dorsal view of winged female, with enlargements of ovipositor, head, antenna, wing margin, and leg at d, e, f, g, h, i (reduced from Riley and Howard).

The damage occasioned by it is greatly increased by the secretion, in the larval and pupal stages, of a honeydew similar to that secreted by the true scale insects. This is in enormous amount, and the sooty mold which develops in it frequently covers the entire upper surface of the leaves and produces very serious effects on the vitality of the plant; the fruit does not ripen properly, is deficient in quality and size, and keeps poorly, involving in addition the expense of washing before it can be marketed.

The life round of the insect, briefly, is as follows: The winter is passed in the mature larval stage as a thin, elliptical, scale-like object on the under sides of the leaves. Early in the spring the transforma-

tion to the pupal stage occurs, this stage differing but slightly from the larval in appearance. The adults begin to appear by the middle of March and continue to emerge through April. The eggs deposited by this brood require about three weeks for development, hatching into larvæ from the middle of April to the 1st of May. The adults of the second brood begin to emerge by the middle of June and continue to appear until the middle of July. Between the middle of July and the middle of September a third brood is developed, the larvæ of which, hatching about the last of October, carry the insect through the winter. The number of eggs laid by a single female is in the neighborhood of twenty-five, and they are placed, by preference, upon new leaves, but all of the plant is taken when the multiplication of the insect makes it necessary. The young larva is active, resembling closely the larva of a true scale insect. The life of the adult ranges from ten to twenty days.

The most satisfactory remedies for this insect, as demonstrated by Messrs. Swingle and Webber, are the kerosene and resin washes. The treatments may best be made during the winter, between December and March, and again, if necessary, in May, and also in August or early in September. Two or three applications may be made in the winter. The application in August is made if the sooty mold is found to be spreading to the fruit. Since the insect lives on the under sides of the leaves almost exclusively, it is of prime importance that the under surface be thoroughly wetted with the spray, and it is necessary that the tree be opened up by pruning. Fumigation with hydrocyanic-acid gas is also a ready means of destroying this insect. It is undoubtedly kept more or less in check by parasitic and predaceous enemies, and is subject to attack by several fungous diseases, which may be of occasional value in preventing its undue multiplication.

THE RUST MITE OF THE ORANGE AND THE SILVER MITE OF THE LEMON.

This mite (*Phytoptus oleivorus* Ashmead—fig. 33) is an enemy of both the orange and lemon, affecting these fruits in a somewhat different way. For many years this mite was known only in Florida, and its injuries were notable only in the case of the orange. It is probably native to the Florida peninsula, possibly having originally some food plant other than the orange.

The lemon and orange groves of California were for a long time entirely free from the attacks of this mite, but about 1889 some car-loads of citrus trees were taken into California from Florida and planted, without careful inspection, in the Rivera and San Diego Bay districts. This shipment of trees brought with it, unfortunately, two or three of the Florida scale insects, and also this rust mite, which has gained a foothold in the important lemon districts about San Diego,

and is now one of the worst pests the lemon grower has to deal with. For a number of years the effect of its attacks in California was ascribed to a fungous disease, and it was not until the writer visited the lemon districts about San Diego Bay in 1896, and identified the injury as due to the Florida rust mite, that its true nature was known. Our knowledge of its life history and habits and the remedies for it are chiefly due to the work of Mr. Hubbard in Florida.

This mite develops on both the leaves and fruit, although its presence on the former is often overlooked. On the foliage the presence of the mite causes the leaves to lose their gloss and become somewhat curled, as though by drought. The leaves are never killed, however, the attack resulting merely in the considerable checking of the vigor of the plant.

The presence of this mite affects the fruit of the lemon slightly differently from that of the orange. The ripening fruit of the orange, after having been attacked by the mite, becomes more or less rusted or brownish, and the rind is hardened and toughened. While the orange loses its brilliant fresh color and gloss, the toughening and hardening of the rind enables the fruit to stand long shipment, and protects it very materially from decay. The quality of the juice is rather improved by the mite than otherwise, the mite-attacked oranges being more juicy and sweeter flavored. As a result of this, a demand grew up in the Northern markets for the rusty fruit, and good prices were obtained for it.

In the case of the lemon, however, an injury to the rind is an important consideration, a perfect rind being a requisite of the fruit, on account of the numerous uses to which the rind is put and the valuable products obtained from it. The effect on the lemon is also somewhat different from that on the orange. The rind of both fruits, when attacked by this mite in the green stage, becomes somewhat pallid or "silvered," due to the extraction of the oils and the drying up and hardening of the outer layer of the skin. This whitening is much more marked with the lemon than with the orange, and, since the lemon is often picked while green, the subsequent rusting is not nearly so notable; hence, in California this mite is known chiefly as the silver mite. If the lemon is allowed to fully ripen on the tree, however, it also becomes bronzed or rusted, but rather lighter in shade than the orange.

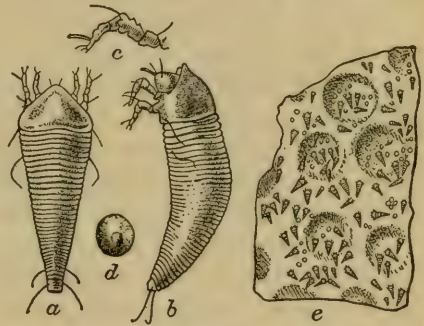


FIG. 33.—The rust or silver mite (*Phytoptus oleivorus* Ashmead). *a* and *b*, dorsal and lateral views of adult mite; *c*, leg of same; *d*, egg; *e*, lemon rind showing pits normal to surface and mites and eggs—all greatly enlarged. (*a* to *d* copied from Hubbard; *e*, original.)

As in the case of the orange, the rind of the lemon is hardened and toughened, but the juicy contents are not affected materially; furthermore, a silvered lemon will keep very much longer than a perfect lemon, and will bear long shipment without risk of much loss. Until very recently the rusted lemon in southern California found no market whatever, and was a total loss to the grower. The scantiness of the crop in 1900 resulted, however, in some shipments of rusty fruit being made under the name of "russet lemons," about half the normal price being obtained. Should the manufacture of citric acid assume very much importance in southern California, the mite-injured lemons could be used for this purpose. Nevertheless, considering the ease with which the mite may be controlled, there is no excuse for allowing it to maintain itself in injurious numbers in a lemon grove, since, irrespective of the appearance and value of the fruit, its work on the foliage materially lessens the healthfulness and vigor of the plant.

The rust mite avoids exposure to sunlight, and hence the lower half of the fruit is nearly always first invaded, and only gradually does the mite work its way around to the upper surface, very frequently a small portion exposed to the direct rays of the sun remaining unattacked. This gives the appearance, most prominently shown in the case of the orange, of a discolored band extending about the fruit. The multiplication of this mite goes on at all seasons of the year in the orange and lemon districts, being merely less prolific and active in winter than in summer. It has been supposed in Florida that dry weather is inimical to it, but the fact that it thrives in southern California would seem to throw doubt on this belief.

The rust mite itself is very minute (fig. 33), practically invisible to the naked eye. It is honey-yellow in color, and about three times as long as broad. It is provided with four minute legs at its head extremity, by means of which it drags its wormlike body slowly from one spot to another. The eggs are circular and are deposited singly or in little clusters on the surface of the leaf or fruit. They are about half the diameter of the mother and nearly transparent in color, having, however, a slight yellowish tinge. They hatch in four or five days in hot weather, but in cold weather the egg stage may last for one or two weeks. The newly hatched mite is very similar to the adult. About a week after hatching, it undergoes a transformation, or molt, requiring a period of about forty-eight hours, after which it escapes from the old skin, which remains adhering to the leaf or fruit for some little time. This moult brings the mite to its adult stage, in which it is somewhat darker in color than the young and opaque. No sexual differences have been discovered, and the number of eggs deposited by a single mite is not known. The entire development of the mite is short, probably not much exceeding, in warm weather, two weeks.

The food of the mite seems to be the essential oil which is abundant

in all the succulent parts of citrus plants, and which is obtained by the mites by piercing the oil cells with their beaks.

These mites, while excessively minute, are capable of very active locomotion, moving from one part of the leaf to another, as the conditions of light and food necessitate.

An estimate, made from actual count, indicates that the mites and eggs on a single leaf in midwinter may reach the enormous number of 75,000. This indicates for trees, in the active breeding season of summer, billions of mites. The mite is very readily distributed by means of insects and birds.

The rust mite is readily destroyed by various insecticides. The eggs, however, are much more difficult to kill, and practically no wash can be relied upon to reach and destroy all the eggs of this mite. Experience in California indicates that gassing is also ineffective against the eggs. The sovereign remedy for the rust mite is sulphur. It may be applied as a powder on trees, and, moistened by rain or dew, will adhere to the leaves for quite a long period, not being readily washed off even by a hard rain. When spraying is done for scale insects, the flowers of sulphur can be mixed and applied with the spray, accomplishing both purposes at once. A better method, perhaps, is to first dissolve the sulphur with lye, as follows:

Mix 20 pounds of flowers of sulphur into a paste with cold water, then add 10 pounds of pulverized caustic soda (98 per cent). The dissolving lye will boil and liquefy the sulphur. Water must be added from time to time to prevent burning, until a concentrated solution of 20 gallons is obtained. Two gallons of this is sufficient for 50 gallons of spray, giving a strength of 2 pounds of sulphur and 1 of lye to 50 gallons of water. An even stronger application can be made without danger to the foliage. This mixture can also be used in combination with other insecticides.

There are several species of mites which attack citrus plants, the most troublesome one of which, especially in Florida, is the one named above. Almost any insecticide will kill the adult mite, such as kerosene emulsion, resin wash, or even a simple soap wash, but unless the eggs are killed the trees will be reinvaded about as thickly as ever in the course of a week or ten days. The advantage of the sulphur treatment arises from the fact that the sulphur adheres to the leaves and the young mites are killed as soon as they come in contact with it.

THE SIX-SPOTTED MITE.

This leaf mite or spider (*Tetranychus sexmaculatus* Riley—fig. 34), is closely allied to the common red spider of greenhouses. It first made its appearance as an important orange pest in Florida in 1886. Following the severe freeze of the winter of 1885-86, the weakened trees

seemed to be especially favorable for the multiplication of this mite; it increased suddenly in enormous numbers during the dry weather of the early summer and was responsible for very considerable damage to the foliage of the orange.

The original food plant of this mite is unknown. It was first noted on wild orange, from which it spread to other citrus trees. It is probably a native of Florida.

Like its allies, this insect is greatly influenced by climatic conditions, and needs for its excessive multiplication dry hot weather. Therefore, in rainy seasons it is not especially troublesome, and it usually disappears as soon as rainy weather sets in. In Florida its period of greatest

destructiveness falls between February and the middle of May. This mite was carried to California a decade or more ago with Florida stock, doubtless at the same time that several other Florida citrus insects were transported to the Pacific coast. In California, however, the principal mite injury seems to be due to an allied species, also brought from Florida, *T. mytilaspidis*.^a

The attacks of the six-spotted mite are confined largely to the under sides of the leaves, which are covered with a fine web, beneath which the mite feeds. The first indication of its presence is usually a yellowing in streaks and spots of the upper surface of the leaves. The under surface becomes soiled by the accumulated excrements in the form of minute black spots and by the web of the mite. On badly attacked trees the foliage curls and shrivels and the trees

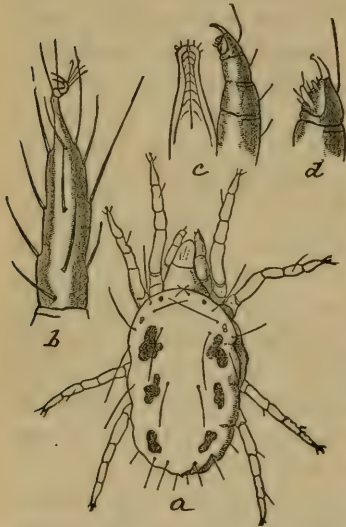


FIG. 34.—Six-spotted mite of the orange (*Tetranychus sexmaculatus*): a, dorsal view of adult mite—vastly enlarged; b, greater enlargement of foot; c, d, mouth parts (from "Insect Life").

may lose half or more of their leaves, and similarly also a large percentage of the half-formed fruit. Being an accompaniment of drought in Florida, part of the damage may undoubtedly be ascribed to the effect of the dry weather.

The remedies are the same as for the rust of silver mite. The bisulphide of lime is also an effective wash. It can be made very cheaply by boiling together in a small quantity of water equal parts of lime and sulphur. Five pounds of lime and 5 pounds of sulphur, dissolved by boiling, should be diluted to make 100 gallons of spray. Gassing is ineffective.

^aSee Bul. 145, Cal. Agr. Expt. Sta., for detailed account of this species.

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 178.

INSECTS INJURIOUS IN CRANBERRY CULTURE.

BY

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WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1903.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., June 29, 1903.

SIR: I have the honor to transmit herewith an article on Insects Injurious in Cranberry Culture, prepared by John B. Smith, professor of entomology, New Jersey Agricultural College, and recommend that it be published as a Farmers' Bulletin.

Respectfully,

L. O. HOWARD,
Entomologist and Chief.

Hon. JAMES WILSON,
Secretary of Agriculture.

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INSECTS INJURIOUS IN CRANBERRY CULTURE.

INTRODUCTION.

The method of cultivating cranberries is so radically different from that employed for any other crop, and the character of the soil on which the plants grow is so unlike that on the ordinary farm, that it is not surprising to find the insect enemies more or less peculiar in character and the methods of dealing with them unusual.

The general practice is to cover the bogs with water during the winter, and this excludes from them quite a variety of insects that might otherwise prove troublesome. In a few localities where winter flowage is impossible, some insects that are not usual on other bogs do injury, and these must be dealt with as similar species would be treated if affecting upland crops. With a bog properly located, properly laid out, and a suitable amount of water supply to cover it promptly in case of necessity, the cranberry grower need fear none of the insect pests so far known as injurious to the crop.

Roughly speaking, the species of insects injurious to cranberries are divided into such as affect the foliage, such as attack the stem, and such as injure or destroy the fruit. Under the first head come the leaf folders, like the black and the yellow head cranberry worms, the tip worm, and the different spanworms which appear in variable numbers each year. Under the second head comes the stem girdler, which eats the bark of the stem or runners and thus kills the plant beyond the point of attack. Under the third head comes the berry worm and the various grasshoppers and katydids that eat of or into the fruit.

INSECTS THAT ATTACK THE FOLIAGE.

THE BLACKHEAD CRANBERRY WORM.

(*Eudemis vacciniana* Pack.)^a

This is perhaps the best known and most uniformly injurious of all cranberry insects and is locally known as the "vine worm" in Massachusetts and as the "fireworm" in New Jersey. As a larva (worm) it is a deep, rather velvety, green, slender little caterpillar, not over

^a Also mentioned in entomological writings as *Anchylopera* and *Rhopobota*.

half an inch long when full grown, and with a shining black head and neck. The adult is a small moth or "miller" with narrow, dusty-brown wings that measure less than half an inch when expanded and seem much smaller because they are so slight. More closely examined



FIG. 1.—Moth of blackhead cranberry worm (after Riley).

the fore wings will be found to have alternate light and dark gray-brown shade bands, obliquely arranged as shown in fig. 1.

The moths first appear on the bogs in early June, continuing until nearly the end of the month, and again late in July, continuing into August, when they disappear for the season. During the day little is seen of them unless the vines are disturbed, when they flutter away for a short distance, concealing themselves so closely as to be almost undiscoverable unless the actual point of settling has been noted. In the early evening and until the darkness sets in fully they are on the wing and hover a short distance above the plants like a swarm of mosquitoes.

Though the moths themselves have disappeared for the season before the end of August, they have left, scattered everywhere on the undersides of the leaves, their minute yellow eggs (fig. 2). These eggs are flattened, disk-like, and less than half the size of an ordinary pin head, but their bright yellow color makes them easily visible against the green of the leaf, even without a magnifier. There they remain throughout the winter, whether the bog be dry or flowed, and the little caterpillars hatch from them in spring as soon as the temperature reaches an average of about 60 degrees. Many of the eggs perish during the winter, but where the vines are uncovered in sheltered spots they hatch out little worms about the time the vines themselves

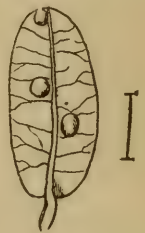


FIG. 2.—A cranberry leaf, showing eggs of blackhead (after Smith).



FIG. 3.—First web of larva of blackhead (after Smith).

are making a start. For a day or two the worms nibble on the under surface of the old leaves or may even burrow into them and then make their way to the tip of an upright, where they spin together the edges of the new leaves.

The experienced grower, if he walks among his vines a few days after they have made a start, can tell at a glance to what extent his bog is infested by the closed tips (fig. 3) that are prominent because the light undersides of the leaves are visible. In about three weeks from the date

of hatching, the caterpillar is full grown, lines the inside of its shelter more fully and closely with fine silk, and changes to a stubby little yellowish-brown pupa (fig. 4). In a week the transformation is com-

pleted and the moth appears about the 1st of July. The bog at the beginning of July shows very plainly the effects of the insect's attack in brown tips that are everywhere noticeable; and every brown tip at this time means a barren upright.

Next the leaves drop and the burnt appearance disappears for a few days, but this is only to give way to another series of spun-up tips which resemble those of the early brood, but with a difference. The vines are now in full foliage, full of buds and almost ready to bloom. Unlike those of the first brood, the worms of this second brood are not content to spin up only a single tip; they gather into their web everything within reach (fig. 5).

Two or three sprays with all their buds may be included and every chance for fruit destroyed. In fact, the buds, flowers, and very young

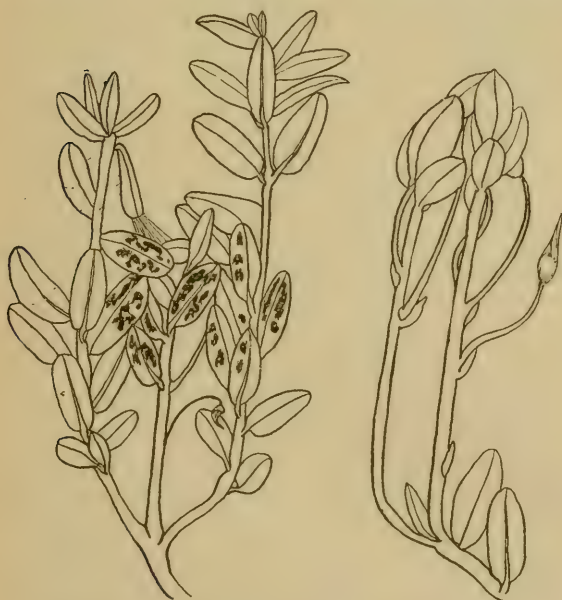


FIG. 5.—Examples of feeding and of webbed uprights (author's illustration.)

berries are eaten by preference, and the injury to the crop is out of all proportion to the amount of plant tissue actually devoured. So, also, instead of eating up a leaf entire, the worms take a few bites here and there until, toward the end of July, the bog appears as if it had been burnt over, justifying the term "fire-worms" for the insects.

The egg stage for this second brood is less than a week in length, the larvæ

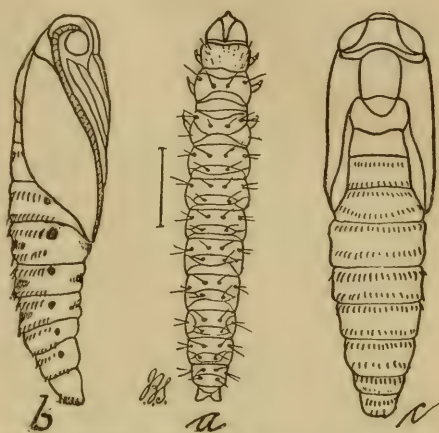


FIG. 4.—Blackhead cranberry worm; a, larva, b and c pupa—enlarged (author's illustration).

by the middle of July the moths are again out in full force. Egg laying is in full swing before the end of the month and these eggs do not hatch till the next

year. The cranberry vines will recover in appearance, and by the middle of August look green and flourishing; but if the worms have been numerous there will be no berries.

Remedies.—The question of remedial measures will be considered after the description of the next species, as the two need similar treatment.

THE YELLOWHEAD CRANBERRY WORM.

(*Teras minuta* Rob.) ^a

This insect is much more abundant in New Jersey than it is in Massachusetts, and in some localities in the latter State it does not seem to occur as a cranberry feeder at all. It is quite as plentiful on Long Island as it is in New Jersey, and wherever it occurs is apt to be even more injurious than the preceding species.

The common name here used describes the most conspicuous difference in the larval (worm) stage from the preceding species, and is employed in preference to the term "vine worm" under which it used to be best known in New Jersey. In this species the eggs are not on the bogs during the winter. On the contrary, the moths themselves hibernate in any shelter they can find—in cranberry houses, barns, or other buildings; under bark or bark scales on trees, and in numerous other places where they may find protection from the direct influence of the weather. At this season the moths are uniformly slate gray, inconspicuous, much broader winged than the moth of the "black-head worm," and apparently much larger in every way. They are on the wing as soon as vegetation starts in spring and are ready to lay their eggs during the latter part of April and early May. They prefer cranberry if they can get it; but if not, make a shift with huckleberry or some allied plant, or even with apple. Wherever cranberry vines run up on the dams above the water line, or are otherwise not submerged, eggs are laid on the underside of the leaves. These eggs resemble those of the blackhead species so closely that, except for their fresher, brighter appearance, no differences can be observed even with a good hand lens. By the middle of May in New Jersey, and perhaps a little later in Massachusetts, all the moths have disappeared. This habit is an important one from the practical point of view and gives in some localities practical control of the insect. The eggs hatch in a week or ten days—depending much upon the weather—the worms make their way to the tips and spin together the terminal leaves, exactly as do those of the preceding species. The yellow head is practically the sure mark to tell this kind from the blackheads.

^a Treated in works on economic entomology, also, as *Teras vaccinivorana* Pack.

This matter of distinguishing between the two is of decided importance, because, while the feeding habits are similar, there are vitally important differences that affect remedial measures. The yellowheads are, on the whole, stouter than the blackheads, and, as a rule, lighter in color. They are also less active and, especially when nearly full grown, do not so readily wriggle out of their nests.

The yellowheads grow fast, and are ready to pupate late in May or very early in June, a little before the blackheads. The second moths appear early in June, but are now bright orange red in color, whereas the first moths were slate gray. The second lot of eggs hatch toward the end of June, and the yellowhead worms are nearly half grown when the cranberries are in full bloom, early in July, when the second brood of blackheads has just started. They make even larger webs than the blackheads, and are even fonder of boring into the fruit. It is not uncommon to see half a dozen uprights and runners all tied together in one large web, in which leaves, even if not eaten, turn brown and die. By the middle of July or a little later the yellowheads are again full grown and change to pupæ. The worms spin a silken cell, in which the change takes place, and the pupa (fig. 6) is dark brown or blackish, with a little knob-like protuberance on the head case. This peculiarity makes the species easily distinguishable from the same stage of the blackheads.

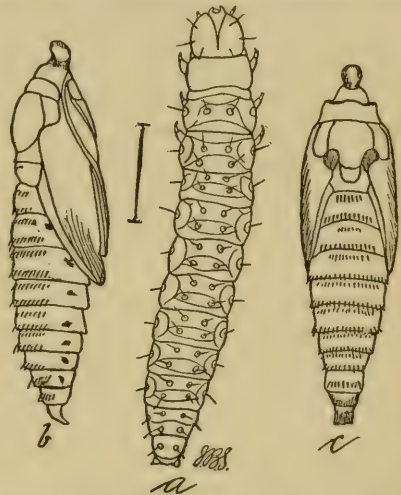


FIG. 6.—Yellowhead cranberry worm; a, larva; b and c, pupa—much enlarged (author's illustration).

The third crop of moths appears late in July or early in August and are of the same orange-red color as the second. Eggs laid by these moths do not hatch until in August or even early in September, and the worms that come out of them grow slowly as compared with the earlier broods. Few of them spin up more than a single shoot and few of them eat into any but the smallest berries. They also tend to become reddish in color and even striped, so that at one time they were believed to form a distinct species, described as the "red-striped cranberry worm." Not until after the picking, if anything be left to pick, do these worms become full grown. Very irregularly in late September and early October they come to maturity, and now the moths that come from them are, after a dust of orange wears off, of the slate-gray color seen in spring.

NATURAL CHECKS.

The blackhead worms are little, if any at all, subject to parasitic attack. The check for these seems to come in the mortality among hibernating eggs. Only a small fraction of those that are on the plants in midsummer survive to hatch during the following spring. But while the blackheads are kept within certain bounds by these natural conditions, they do very serious injury to the cranberry crop.

The "yellowhead" (Teras) is much more subject to parasites, though the first brood of worms is but little attacked. In the second brood matters have changed, and out of a given number of worms collected near maturity less than 50 per cent became adult. In the third brood conditions are yet further modified and not over 25 per cent of the worms develop to the adult stage, leaving, however, a goodly number to go into the winter. During this season many others die off because of adverse weather conditions, but still enough remain.

In general, on any given infested area, both of these cranberry worms will hold their own and even increase under natural conditions. The grower has nothing to hope for from the ordinary checks provided by nature.

REMEDIAL MEASURES.

Flowing the bog.—The application of insecticides on large bog areas where the plants cover the ground as densely as do the cranberry vines is a task no grower likes to contemplate; and provided he has control of a satisfactory amount of water there is no necessity for it. As against the "yellowhead" (Teras), it will suffice if the water be held on the bogs until the middle of May, or perhaps a little later in cold seasons. By this time the huckleberry and heath plants have made a good growth and have tempted the hibernating moths to lay their eggs. Unless, therefore, the vines are uncovered at the edges or on knolls above water, the plants will be free from the first brood of worms. In the woods and on the upland plants the worms and even the moths are exposed to the attacks of birds and many predatory insects that never go upon the bogs; hence the adults of the first summer brood will not be nearly as plentiful as if they had bred on the vines. Only a few, comparatively, of the moths will fly upon the bogs, and even then do not usually get very far from the edges; so the heavy, very injurious middle brood will be reduced to practically harmless numbers. The third brood, even if it does spread over a greater area, is not likely to prove troublesome, for reasons already stated. Hence, care and attention to the drawing of the water in spring will of itself suffice to keep this insect in check. If to this we add the destruction of the heath and huckleberry plants immediately surrounding the

bogs, the nearby breeding places are further reduced and the bog is the more likely to remain free.

As against the blackhead late holding will not of itself suffice, because the eggs are already on the plants and will, under ordinary circumstances, hatch only under the same conditions that favor the start of vines themselves. But there is a little leeway in favor of the plants, and the eggs do hatch under water at a temperature not quite sufficient to start the vines. To hatch the eggs the proper temperature only is needed; to start the vines there must be also sun and air. If, therefore, a bog is tolerably level the water may be drawn from below until it just covers, and may be held there even after May 15, until the starting of the vines indicates that the danger point has been reached, and then it must be drawn to avoid killing the fruit buds. Runners or laterals not bearing fruit buds will stand a quarter or even half an inch start under water without danger unless the water is drawn on a very warm day, and then there is danger of scalding. The further advanced the plants the greater that danger becomes; hence great care and good judgment must be exercised when this measure is adopted. Fruit-bearing uprights can not be safely permitted to make more than a mere start. On a sloping bog, where the water is deep at the gates and becomes shallow at the edges, the water may be gradually drawn from the bottom so as to leave the warmer surface water, and in this way practically all the eggs will come under the influence of the moist heat that favors their development.

Carefully carried out, this measure is often very effective; the warmth favors the development of the embryo within the egg, and when the worm hatches it drowns. Occasionally a specimen may bore into a leaf and so maintain itself twenty-four hours or more, but usually it stifles without getting even a bite. Sometimes badly infested bogs are completely freed by this method without apparent injury to the setting of fruit, yet at times the crop is reduced one-half by holding a little too late. In the latter case, however, the crop had been destroyed by the insect for several years in succession, and the owner was quite willing to sacrifice 50 per cent if thereby he got rid of the insect, as he did. This method should be employed only when reflowing is not possible.

Reflowing.—When the supply of water is abundant above the bog area, so that a pond or reservoir may be formed, both the yellow and blackheads may be completely controlled by drawing the water early, waiting until all the eggs have hatched and some of the worms are nearly half grown, and then re-covering the bog with water for forty-eight hours. This method is so simple and so absolutely effective that the larger growers are adopting it almost universally, and few new bogs are laid out anywhere without considering the matter of reflowage and

providing for as good a control of the water as possible. Under proper control the water may be drawn from the bogs when the best interests of the plant demand it without any regard to insect conditions. If worms appear in any number toward the end of May, the bogs are reflowed, and rarely is this necessary more than once in three years. Only when the bog area is small and the surroundings are very bad is annual reflowage needful. For a complete effect the vines should remain covered forty-eight hours, because it requires some time for the water to penetrate the spun-up leaves so as to kill the worms. Many, indeed, especially the half-grown blackheads, wriggle out, seeking to escape when the water reaches them, but those nearing maturity are less active, remaining at home until the water surrounds them and they simply can not get out. Covering the bogs should begin in the late afternoon and should be completed before next morning, if possible. On a rainy day it may begin at any time, the object being merely to prevent the sun from boiling the young shoots. So drawing off the water should also begin in the early afternoon, and the bog should be practically dry the morning after. Incidentally, this reflowing will rid the bog of numerous other pests and may make a material impression on the girdle worm where that is abundant.

The importance of a sufficient water supply has come to be so generally recognized among advanced growers that in New Jersey miles of ditches tap streams far away from the bogs, and in Massachusetts expensive pumping machinery has been installed to raise water in large quantities to high-bog areas.

It is sometimes possible to use the upper one of a series of bogs as a reservoir, holding a full head of water as late as it is safe to reflow the lower bogs of the series which have been drawn early. In one series of 100 acres, divided into 5 sections by cross dams, a fall of about 10 feet is utilized to reflow all save the uppermost section, and this practice is possible in almost every case where water is available.

Insecticides.—Sometimes it happens that bogs can be neither winter flowed nor reflowed, and the application of insecticides becomes an absolute necessity. Only arsenites are to be relied upon for good results, although for a long time tobacco was and in some parts of Massachusetts is yet the main reliance. It follows from what has been said concerning the habits of the worms that when once they have spun up the tips and are feeding in their cases they are practically beyond the reach of our common insecticides; and that is particularly true of the first brood. If there is reason to believe from past experience, or because eggs have been found on the plants, that the early brood will be numerous, spraying must be done just as soon as the vines make a start or not later than the date when the first spun-up tip is seen. The object is to get the poison into position before the leaves are spun up, so that the worms may find their first meal poi-

soned. If spraying for the first brood is omitted, that for the second brood should be timed in the same way, and, because the worms now spin up a greater amount of vegetation, the chances of killing them off are greater.

All things considered, the best insecticides for use on cranberry bogs is arsenate of lead, either in the paste form as sold by certain makers of insecticides or made up by dissolving separately 4 ounces arsenate of soda and 7 ounces acetate of lead in water enough for that purpose, then combining the solutions in a tank to which 50 gallons of water may be added. If the paste arsenate is used, 1 pound in 40 gallons is better.

Any sort of machine or pump may be used and any nozzle that makes a reasonably fine spray. The point to be aimed at always is the terminal growth, because it is there that the insects feed. Nothing will be gained by driving the mixture into the body of the vines, especially if they are long and densely matted. The conditions on the bogs vary so much that every grower must determine his outfit according to his own needs. In some cases horses can be used on the bogs to draw a geared machine of large capacity; in others they are out of the question; and so the size of tank from which the spraying is done and the way in which it is mounted must vary according to circumstances.

It may under some conditions be more satisfactory to apply a dry insecticide, and for this purpose there are now several "dust sprayers" and "powder guns" on the market. By means of a fan blower a fine powder can be rapidly and evenly distributed over a large area, and this would naturally lodge just where it was needed. A good mixture for such application is 1 pound of fine Paris green to 10 pounds of dry hydrate or fresh air-slaked lime. The lime should be sifted, thoroughly mixed with the Paris green, and the combination applied while the vines are slightly moist.

THE CRANBERRY TIP WORM.

(*Cecidomyia oxycoccana* Johns.)^a

This is a minute orange-red or yellowish grub (fig. 7, *a*), about one-sixteenth of an inch in length, found in the growing shoots, whether uprights or runners. It is comparatively rare on Cape Cod and is not common on all the New Jersey bogs, though more plentiful there than anywhere in Massachusetts. It appears on the vines soon after they make a start, and the first indication of its presence is when the small leaves of the tip cease to unfold and become bunched into a compact, bulb-like mass. When this mass is opened, from one to five,

^aHas been described and figured also as *C. vaccinii* Sm., not Osten Sacken.

and usually two or three, of the little grubs will be found at the very heart of the growing tip, feeding upon the juices and completely checking growth (fig. 8). If it is a runner that is attacked, it is destroyed; if a fruit-bearing upright, the flower buds come out below the infested tip and no harm is done to the crop. But the insects continue to appear on the bogs at intervals throughout the season, and the danger is that the late-tipped uprights will form no fruit buds for the next year.

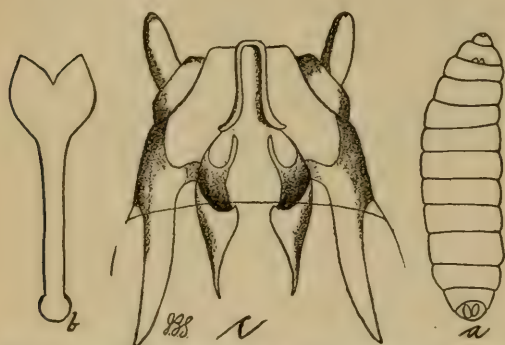


FIG. 7.—Cranberry tipworm; a, larva; b, breast bone; c, mouth parts—much enlarged (author's illustration).

The little grub is rather a helpless sort of a creature, without legs and even without distinct jaws; but

it has on the underside of the body a little horny process or breast bone by means of which it scrapes the plant tissue until the cells break down and their contents may be absorbed. In about ten days it reaches full growth, envelops itself in a thin, white, silken cocoon,



FIG. 8.—Work of tipworm (author's illustration).

and two or three days thereafter changes to an adult—a minute, two-winged fly or midge whose wings when expanded measure less than an eighth of an inch from tip to tip. The male is quite uniformly yellowish-gray and inconspicuous, but the female has the abdomen

deep red, the upper surface of the body gray, the sides yellowish, the head and eyes black. She also has a slender, extensile tip to the abdomen, by means of which the minute white eggs are laid in the very heart of the bud.

After the fly has emerged from one of the infested cranberry tips the leaves that were massed together turn red or brownish, die, and break off, leaving a stub above the fully developed leaves. If the tips are killed early in the season fruit buds may form at the axils of the leaves, or one or more little spurs may start lower down on the shoot, at the tips of which normal fruit buds may develop. On new bogs, with young, vigorous vines, the early broods cause no damage at all and the late broods very little. On old bogs, with long vines, the earlier broods do little harm, but the later broods materially injure the crop prospects for the year following by preventing the set of buds on the injured uprights.

Remedial measures.—Strictly speaking, no direct remedial measures are known. It is not known positively how the insect passes the winter; hence control can not be attempted at that season. The worm never comes within reach of our ordinary insecticides, and therefore direct attack is not possible. Since the loss of the tips attacked in spring does not injure the crop of that year, the effort must be to keep the vines in such vigor that they will set fruit buds on laterals and at leaf axils when the direct tip has been lost. How this vigorous growth is to be obtained the grower will be best able to determine.

This insect is not confined to the cranberry, and in fact breeds much more abundantly on loose strife (*Lysimacha*) and on some of the heaths. Therefore, where the species is troublesome, those plants should be kept down on the dams and other bog surroundings. Tip worms occur on both flowed and dry bogs, and reflowing does not reach them; but as they first occur on flowed bogs around the edges, the inference is that the winter is passed on the upland, on or in some one or more of the alternate food plants. This would make the destruction of such plants an effective measure.

THE CRANBERRY SPANWORM.

(*Cleora pampinaria* Gn.) ^a

In some sections of Cape Cod certain "span," "inch" or "measuring worms" occasionally become injuriously abundant, and the most destructive of these is the species above named. The parent moth is much larger than any of the other forms found on the bogs, the broad fore wings expanding 1½ inches or thereabouts. In general color it is pale ash gray, sprinkled with black, and both wings are crossed diag-

^a Also known as *Boarmia pampinaria*, etc.

onally by black lines and shades. The lines have a tendency to become toothed or scalloped, and the wing margins themselves are also a little notched. The worms first appear on the bogs in June and become full grown by the end of that month or early in July. They are then rather more than an inch long; slender, smooth, livid gray caterpillars with a deeply indented head and a long, pointed anal plate. They have three pairs of short legs close behind the head and two pairs near the anal end. When they walk, they first stretch out at full length, take hold with the anterior legs, then bring the posterior pairs close to the others, the middle of the body forming a loop. This mode of progression gives them the common name "loopers" in addition to those already mentioned. At rest or when not feeding, the caterpillars hold fast by the anal legs only, and stretch out the remainder of the body at an angle, and so rigidly that they resemble leafless bits of vines. On a section of bog on which they have been feeding the observer may stand in the midst of thousands of them and see none until something starts them into motion; then it appears almost as though the entire bog was alive.

When full grown they bury themselves a short distance beneath the surface and change into rough, brown, rather stubby pupæ, from which the moths emerge a few days later. The second brood of caterpillars matures early in August, and pupation begins before August 9. Though worms will continue to be present in numbers until after the middle of the month, the moths appear at its end and in September.

There seems to be no regularity in the appearance of these insects. In some years they are not seen at all; in others they may be locally abundant, and only occasionally do they seem to occur everywhere in great armies. Usually they start from some point near the edge of the bog, spread out a little, and then move in an almost direct line ahead. Sometimes the beginning is nearer the center, and the eating may be in all directions from a given point where some groups of eggs were laid. It is the first brood which, as a rule, starts near the edges. The second brood starts from inside centers, and when these are numerous the boundaries of the individual broods become lost, and, the masses uniting, an army is formed which, as it advances, plays havoc with the crop. Not a green thing is left on the vines, and in a few days acres may change from green to brown; from a smiling promise of a full crop to the barrenness of desolation.

Remedial measures.—Being an open feeder upon the foliage, this span worm is susceptible to arsenical poisoning, and unless the bogs can be rapidly reflowed and as rapidly laid dry, spraying or dusting are the only alternatives. Where the worms are noticed when they first start, spraying the foliage just ahead of them may answer all purposes, and indeed this poisoning of their line of advance should always be done before treating the parts already infested. Either Paris green,

at the rate of 1 pound in about 160 gallons of water, may be used, or the arsenate of lead or a dry powder may be applied, as for the black-heads and yellowheads. So, also, the machinery to be used and the manner of application may be along the lines suggested on page 17.

OTHER CRANBERRY LEAF-FEEDERS.

Quite a number of species other than those already mentioned occur on cranberry foliage from time to time and cause local, though usually slight, injury.

The caterpillars of some of the "owlet moths" are always found in small numbers; but, except for the army worm, none have ever caused widespread trouble. As army worms can not live over on the bogs and must come on from the outside, a broad marginal ditch, well filled with water, will be a perfect barrier to their injury.

Spanworms are much more common, and the striking yellow and black larvæ of the white, chain-dotted geometer are sometimes as plentiful in New Jersey as in Massachusetts; but usually they are on bogs that run up into the huckleberry and heath bushes. They are not strictly cranberry feeders, but will run into the bogs when they become unusually abundant or when for any reason their normal food supply is scant.

Leaf hoppers of various species are more or less common always, and sometimes quite abundant; but, though they undoubtedly drain the plants to some extent, they seem to cause no injury to the crop.

Leaf rollers other than the yellowhead and blackhead cranberry worms are occasionally found. They usually make webs of such different forms that they are readily distinguished from the common species. None of them live exclusively on the bogs, and generally they do not appear until after midsummer.

A saw fly larva (worm) is sometimes found on New Jersey bogs and often eat little round holes in the young berries. It makes no sort of web and feeds only at night, its injuries being thus more readily found than the insect itself.

None of these species is of sufficient importance to demand more detailed notice here. As a rule the injury done is so slight that it will not pay to adopt remedial measures. If real damage is threatened, the arsenical applications are indicated except in the case of the leaf hoppers.

INSECTS THAT ATTACK THE STEM.

THE CRANBERRY GIRDLER.

(*Crambus hortuellus* Hbn.)

This species (fig. 9), more commonly known as the "girdle worm," is found abundantly in all the cranberry districts, but it is seriously injurious in Massachusetts only. The larvæ, which are slender, gray-

ish caterpillars, with shining, light chestnut-brown heads, and yellowish thoracic shields, pass the winter in a torpid condition within a silken tube or cocoon, which resists the entrance of water. In New Jersey the adults are found in May, on and around the edges of the bogs; in Massachusetts they do not fly until July, and there is evidence that the worms do some feeding in spring before they actually change to the pupal stage. This change to the pupa takes place in the tube or cocoon made in the previous fall, and on Cape Cod at the latter part of May or in early June. The adult is a pretty little creature, with fore wings expanding about three-fifths of an inch, and is one of the long-snouted moths, the palpi or mouth feelers projecting well beyond the head. The fore wings are rather narrow, very pale straw-yellow in color, with smoky lines in the interspaces between the veins and narrow silvery cross bands at the outer part, near the margin. The hind wings are much broader and of a uniform silvery gray. When the moth is at rest the wings are so closely wrapped around the body that it looks like a narrow whitish cylinder about three-quarters of an inch in length.

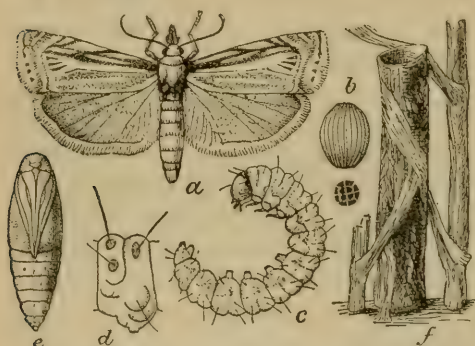


FIG. 9.—Cranberry girdler; a, moth; b, egg; c, larva; d, segment of larva; e, pupa; f, nest of larva—all enlarged (after Scudder).

clusters of new rootlets take their rise. Everywhere over an infested area, but especially along its borders, these worms can be found in filmy silken galleries following the prostrate stems of runners, into the surface of which they eat their way, destroying the vital part of the plant and, especially next to the base of the runners, deeply girdling the stem. They grow rather slowly, and not until November do they make their coarse cocoon of mingled sand and silk that serves as winter quarters.

It seems probable that in Massachusetts there is only one brood of the moths which is active in July. In New Jersey, on the other hand, the moths have been found in every month from about May 21 to the middle of September. There must be, therefore, at least two broods, which develop very irregularly. With this difference in the life cycle in the two States there is an evident divergence in food habits, for

there is no such destruction of large tracts in New Jersey as is found in Massachusetts. That the insect is not specifically a cranberry feeder is proved not only by the fact that it occurs not uncommonly many miles away from any cranberry plantation, but also by the direct evidence of an investigator who actually bred it on the common grasses and found further that the worms would eat freely of sheep sorrel. The cranberry feeding habit seems to be, therefore, a somewhat local characteristic and this gives hope that by persistent work this bog variety may be in large part stamped out.

An infested bog is rarely affected over its entire extent. Small areas varying from a few feet in diameter to half an acre or more are found here and there, and sometimes a little patch only a foot or two across will remain for two or three years in succession without becoming enlarged, but rather it will become closed up by runners from the adjacent healthy vines. Larger areas tend to become larger, new vines dying from the edges each year. A restart over areas so killed out is very slow, yet it does usually occur after the second year; but the growth is apt to be irregular and requires some time before it comes again into bearing condition.

Remedial measures.—It is quite obvious that insecticides are not available here, because of the concealed feeding habit, and that resort must be had to more direct methods. Light traps to capture the adults have proved unsatisfactory, very few specimens having been taken in this way. Experiments show that the worm in its silken case will bear submergence in water for over four days without fatal results, and it is known that in its cocoon it bears submergence during the entire winter. But the insect does not make this cocoon until November, and a submergence of five days immediately after the picking is completed destroys a great many. The suggestion is therefore made that, immediately after the fruit is off, infested bogs be flowed and be kept covered for at least a week, and better two weeks. This should be effective against these worms and harmless to the vines. While the ripening fruit is on, any water covering kept on over twenty-four hours would be apt to do material injury.

An additional suggestion is that the actually infested area be completely burned off as soon as its extent can be determined. The vines already attacked are doomed at best, and if in destroying them the insect can be also killed the loss will be balanced by a greater benefit. For this burning a gasoline torch may be employed, and the heat thus applied directly to the point where it will be most effective. The use of the torch will also prevent setting a fire that might injure other portions of the bog, since it can be used when the vines are so wet that they will not burn under ordinary conditions. The burned-over area can be immediately reset and the actual amount of injury limited to a minimum.

If burning is resorted to, it should be done as early in the season as possible and should be extended far enough to cover the entire infested portion of the bog.

INSECTS THAT ATTACK THE FRUIT.

THE CRANBERRY FRUIT WORM.

(*Mineola vaccinii* Riley.)

This is another species that is much more injurious in Massachusetts than in New Jersey, though it is by no means unknown in the latter State, and in some seasons and localities does considerable damage. As a rule, bogs that can not be reflowed and high and sandy bogs suffer more.

The adult moth (fig. 10) appears on bogs in ordinary seasons about the middle of July, when the berries are setting or have already set. It is probable that the moths remain on the bogs for a period of at

least a month, as indicated by the very unequal development of the worms that are found in the berries in early September.

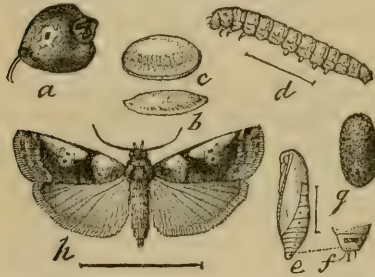


FIG. 10.—Cranberry fruit worm; a, berry, showing egg; b, c, egg; d, larva; e, f, pupa; g, cocoon; h, moth—all enlarged (after Riley).

The moth, with wings expanded, measures about three-fourths of an inch and is of a glistening ash-gray, mottled with white and blackish. The forewings are narrower than the hind wings, which are more smoky gray in color and have no markings.

It is a shy species, not easily started during the day, and flies with a darting motion for quite long distances. It is not generally recognized, therefore, even by growers who annually lose heavily by it. When at rest the wings are folded close to the body, and on a cranberry stem, where it usually rests head down, it is not readily seen even by an experienced eye.

The eggs are laid on the young berry, preferably in the calyx, just beneath one of the lobes, but they may be on any part of the berry and possibly on the leaves as well. They are very slightly convex, almost flat, round in outline, pale yellowish in color, and so soft that they adapt themselves readily to any inequalities of surface. The worms emerge in about five days, and for a day or two feed on the outer side of the berry. Then each worm enters a berry, eats out the seed chamber, and migrates to another. The vacated berry turns red, shrivels up, and eventually drops. The worm, on entering its new home, carefully closes the opening behind it with a web of fine silk, so dense that it is sometimes difficult to see where the hole was made. In this second berry it becomes half grown, then works out through a large

jagged opening and gets into a third berry, closing the point of entry as carefully as before. By this time the season is pretty well advanced, the fruit is of good size, and, soon after the worm starts feeding, the newly infested berry begins to turn red. To the ordinary observer the fruit is ripening nicely, if early; but the grower knows better and realizes that every such specimen is lost to him. Not unusually the worm completes its growth in this berry, but if it does not it eats into a fourth. This time it makes no attempt to seal up its point of entry; very often it spins together a little cluster of berries, eating from one into the other and ruining all of them. Full growth comes, as a rule, in late August or early September, just before picking time; then the caterpillar leaves the berry and in the sand at the base of the plants spins a rather close silken cocoon, in which it passes the winter. But quite frequently the worms do not get their full growth at picking time, and emerge from the berries after they are harvested and in the cranberry house. These delayed forms make their way to any crevice or other shelter that they can find and there spin up for the winter rest.

At this time the worm is rather more than half an inch in length, of a bright-green color, with a variably marked reddish tinge on the back. The head is a little narrower than the first body segment and is of a more yellowish color, except the mouth, which is brown. The body segments are transversely wrinkled, clothed with a few sparse, rather long hairs. As a whole, this is decidedly the stoutest of those occurring on the bog as injurious species.

The full-grown caterpillars winter in their silken cocoons, which they make by first rolling in the sand, gluing the particles together with saliva, and then spinning their web inside of the rough casing so formed. Pupation begins toward the middle of April with specimens that have been dry during the winter, but probably not much before the end of May or early June on the bogs. The pupa is brown, rather chunky, and of the same general form as in the species already described.

Remedial measures. — Winter flowage is not fatal to these insects, and covering the bogs with water at any time after the winter cocoon has been formed would probably be ineffective. Nevertheless, as already indicated, water-covered bogs are less troubled, and it is probable that the earlier the water is put on in the fall the more effective this practice will be.

Indications are that if a bog can be safely submerged for forty-eight hours between August 10 and 15, just before the worms reach their full growth, the great majority will be killed off. Sound berries covered for that length of time will not come to harm if the water can be put on and drawn off rapidly enough to avoid scalding. Fruits not quite so far advanced may be covered for even a longer time without injury, but there is always a risk which the grower should fully consider before he acts. The vines should be completely covered before the sun beats upon them high enough to warm the water, the covering

should be sufficiently deep to prevent a scalding effect, and when the water is drawn sunrise should find at least every berry above the water level, that the drying off may be gradual. A cool day would almost insure safety to the berries, an intensely hot one might cause injury, and the nearer maturity the fruit the greater the danger. Nevertheless, despite the danger, reflowage is advisable, provided it can be done within the time limit given.

If reflowage be not practiced, pick the crop as soon as it is at all practicable, so as to get as many wormy berries off the bog as may be. The worms will emerge in the cranberry house and form their cocoons in cracks and crevices or among rubbish. Give them plenty of shelter in the way of loosely piled slats, boards, or other cover, placed wherever conveniently possible, and any time during the winter clean up thoroughly, so as to reach the hibernating worms. Field mice will eat these worms. Also a liberal use of gasoline in such places under the usual precautions against fire would reach every one of them.

Insecticides are possible only during the two or three days in which the young worm feeds on the outside of the berry, and the only material that offers any chance of good results is arsenate of lead. If when the worm starts feeding it finds a poisonous meal prepared its career will be ended at once. It must be remembered that any application to be at all effective must be on the berries by July 10 and must be maintained there at least a month to get most of the hatching worms. Arsenate of lead is the most lasting of all the arsenical sprays, but new berries are being added constantly as new fruit sets, and at that season growth is rapid, so that a week will add a large amount of new, uncovered surface. One spraying per week for three, or preferably four, weeks offers a fair chance of success by killing off the berry worms before they get into the berry.

On bogs that can not be flowed the arsenate of lead, aided by early picking, will probably reduce the amount of injury materially; but on such bogs the development of the moths may occur earlier and the grower must rely more upon the stage of growth, or, better, the appearance of the moths themselves on the bog, than upon any absolute dates.

Methods of applying the arsenate and of preparing it have been already given on page 17.

THE CRANBERRY KATYDID.

(*Scudderia texensis* Sauss.)

One of the most destructive insects on the New Jersey bogs is a species of katydid (fig. 11), though its injuries are, as a rule, charged to grasshoppers in general. On Long Island the damage is less marked, and in Massachusetts the insect is practically unknown.

The injury is chiefly caused by the feeding habits of the adult of one species of *Scudderia* which chews into the berries when half to full grown, rejects the pulp, and eats the seeds. Other species belonging to *Microcentrum* and other genera have similar habits, but occur more rarely. The injured berries wilt, shrivel, and die; but when they have just been left by the katydids, the common, shorthorned grasshoppers feed on the exposed pulp and, being detected in this, are quite generally charged with having caused the entire trouble. One katydid may eat out several berries at one sitting, and when the insects are at all abundant the percentage of fruit destroyed is very large; on some bogs the amount reaches almost or quite one-half the entire crop.



FIG. 11.—A cranberry-eating katydid (after Riley).

The katydids when mature are green, grasshopper-like insects, with very long antennae, or feelers, and long slender hind legs. The fore wings are also green and are narrow, a little thickened, not used in flight. The hind wings are decidedly longer, much broader, very much thinner, almost transparent, and longitudinally folded under the fore wings when at rest. Fully expanded, these wings measure from 2 to 2½ inches between tips, and the body is about 1½ inches in length. In the male there is a little triangular area at the base of the fore wings where they overlap, and where a few ridge-like veins form a musical instrument by means of which they produce their chirping song or call. In the female this structure is absent, but we find at the end of the abdomen a broad scimitar or sickle-shaped ovipositor, by means of which the eggs are laid.

The young wingless katydids are found around and at the edges of the bogs about the middle of June, but do not mature until early in the following August. Not until they reach the pupal stage, after the middle of July, does the berry-feeding habit become developed, but from that time until the fruit is picked their fondness for this kind of food increases, and the insects themselves increase in number on the bogs. The first eggs are laid about the middle of September and the laying continues until about the same period in October. By that time the insects have disappeared and nothing more is seen of them until June of the following year.

The eggs are laid chiefly in two kinds of grasses, locally known as "deer grass" (fig. 12) and "double-seeded millet," scientifically re-

corded as *Panicum dichotomum* and *P. viscidum*, respectively, the latter being very decidedly the favorite.

The latter, *Panicum viscidum* (fig. 12), is a grass which grows in large tufts or clumps of from 20 to 30 stems, from 2 to 4 feet high, or perhaps 5 feet where it is found in thickets or fence corners. The whole plant is thickly covered with long, soft, velvety, somewhat sticky hairs. The stems are at first not branched and have from 8 to 10 leaves shaped like a narrow peach leaf, those at the top being very small. In summer and fall these stems branch from each joint and the branches keep on branching again and again, producing large numbers of small leaves and giving the plant a very bushy and tangled appearance. The seeds are borne in a small head at the top of each stem and later of each branch, these heads being something like a very small and loose sorghum head or more like a head of broom-corn millet or hog millet.



FIG. 12.—Tip of a spray of *Panicum viscidum*—reduced (after Smith).

The other grass, *Panicum dichotomum*, is much like *Panicum viscidum*, but is very much smaller, scarcely over 18 inches high, and growing in smaller tufts. The stems are slender and weak, and the plant is not at all hairy. It also branches freely in summer and fall. Where growing in the sunshine the stems are usually purplish.

Occasionally eggs are laid on other grasses or plants, but never on cranberry leaves. They are laid chiefly at night on the drier parts of the bog, in the edges of the leaf between the upper and the under surface, to the number of from one to five in one blade; the single number is much the more usual. When deposited the egg is very flat, almost three-sixteenths of an inch long, less than half as wide, slightly kidney shaped and of a very light yellowish brown color. The disk of the egg is closely and roughly marked or netted without definite pattern.

Remedial measures.—The character of the remedy to be adopted follows from the egg-laying habits of the species. Allow none of the host grasses to maintain themselves on the bogs and burn over the dams during the winter while the bogs are flowed. From the fact that the very young katydids are never found on flowed bogs except at the

edges joining the upland or at the base of the dams, it may be fairly inferred that the eggs do not survive the winter when kept completely submerged, so that destruction of the grasses above the water line might answer. It would be safer, however, to have the grasses out; they have no place on the bogs anyway.

For burning the grasses and other host plants on the dams some one of the gasoline torches now on the market may be used. They give a very intense heat and lick up leaves and plants with extreme rapidity. As they can be used against the wind or while the plants are somewhat damp there is practically no danger that the fire will get away, and when the ground is frozen, the covering of leaves and stalks is burned so rapidly that no heat gets to the roots. Growers consider it desirable to keep a cover of vegetation on the dams to strengthen or prevent them from washing, and this method will destroy the egg-bearing vegetation without also destroying the plants themselves.

GRASSHOPPERS AND CRICKETS.

Numerous short-horned and long-horned grasshoppers may be found on and about the bogs, and more or less injury is charged to them. As to the common gray or brown short-horned grasshoppers the charge is believed to be practically unfounded. They do sometimes finish up berries that have been opened by the katydids; but direct evidence is lacking that they would or even could get into a sound berry. Nor do they occur in any numbers on clean, well-kept bogs, free from grass and from overgrown edges or dams. They belong naturally in the grassy undergrowth along the margins, and simply run over when there is an easy opportunity.

It is rather otherwise with some of the long-horned, green, meadow grasshoppers, which on grassy, reedy, or sedgy bogs are sometimes present in immense numbers. All of these are fond of seeds, and while the smaller species can not get into a half or full grown berry, the larger species can, and so they join the katydids in their destructive work, but in comparison do little injury.

Most of them have a long, flat ovipositor, straight or slightly curved, and they lay their eggs in the stems of the sedges, rushes, and larger grasses found on the bogs. None of these species can cut into leaves. Their eggs are long, slender, nearly cylindrical, and often just a little curved. They are laid in series of anywhere from three to eight, one above the other, the number of eggs in any series depending upon the length of the ovipositor in the species.

Where bogs are very full of these little species, a large proportion of the grasses and sedgy plants will be found bearing eggs, and these eggs are so well protected that they survive the winter though they be completely submerged. Accordingly, in early June thousands of

the little meadow grasshoppers are found just hatched and under such conditions that they could not possibly have come on from the outside.

Remedial measures.—The only way to keep these species off the bogs is to keep down the grasses. They are not naturally feeders upon the cranberry plant, and exact so small a toll that the actual loss is less than the probable cost of getting rid of them. If the grasses, etc., can not be readily taken from the bogs, they might be mowed, after picking, above the vine level. This would cut off the parts bearing the eggs, and as the loose grass would float when the water is put on, the eggs would either be carried to the edges or would decay with the vegetation containing them.

Crickets also occur in greater or less numbers on most bogs, and growers are by no means agreed whether they cause injury or not. That they will eat berries on the ground, especially under cranberry crates, is certain; but it is not proved that they ever go upon a vine to feed upon a berry attached to it. The species lay their eggs in sandy soil, and never in wet or mud land; so, as a matter of fact, no field crickets can really propagate on the bogs. But they get into the dams, and oviposit in warm sandy places, so that the young may hatch early in the spring and find their way to the moist, warm places in which they delight. Their range of food seems to be wide, and there is almost nothing they will not eat under favorable conditions; but they live on the ground and rarely get out of the shelter of the vines or upon them.

If it be deemed desirable the crickets can be kept off the bogs almost entirely by broad, clean, marginal ditches maintained at least partly full of water. The crickets rarely if ever fly, and, while they are good swimmers, do not ordinarily attempt to cross any ditch 6 feet wide.

A flowing just after picking would destroy most of the grasshopper and cricket tribe that then occur in their greatest number.

THE IDEAL CRANBERRY BOG.

So much has been said of bog conditions, and bog conditions so greatly influence the abundance of injurious species of insects, that it may not be out of place to describe briefly what a bog should be to make insect control easy and certain.

(1) The bog should be as nearly level as it can be made, so as to require the least possible amount of water to flow it. A bog that can be completely covered by a 12-inch head is better than one that requires 24, and when the difference in level of an area is 5 or 6 feet or more it is better to make two bogs out of it, that the lower may be reflowed from the upper and less than half the amount of water be required.

(2) Make no one bog so large that more than thirty-six hours are required to cover completely, and no more than twenty-four hours are required to draw the ditch level.

(3) Build a reservoir or reserve a flooded area above the level of the highest bog of a series sufficient to hold water enough to flow at least the highest bog completely. The importance of this requirement is so fully appreciated that miles of ditches have been dug in New Jersey to tap streams at a higher level, and many acres of swamp area have been created by raising contour lines to deepen natural basins. In Massachusetts powerful pumps have been installed to pour water directly upon the bog or into a reservoir above it.

(4) Adjust bog levels so that the upper one of the series can be completely emptied into the one below, and yet have the gates and outlets so adjusted that any one bog may be completely emptied without interfering with either those above or those below. It happens not infrequently that one bog needs cleaning or other attention while others do not.

(5) There should be a broad, deep, marginal ditch between the dam and the bog or between the bog and upland, and this ditch should be always clean and at least partly full of water. Many kinds of insects can be altogether kept from the bogs in this way, while grasshoppers and other insects are delayed until they can fly. Then they are feeding on other things, and they do not often change the food habits of their early life.

(6) The dams and the edges of the uplands should be kept as free as possible from vegetation that harbors cranberry-feeding species. Cranberry vines should not be tolerated for an instant. Huckleberry bushes are almost as bad, and these should be cleared back for some distance where bog and upland join without an intervening dam. Other heath plants are also undesirable and should not be allowed too near the bogs nor on the dams.

(7) It follows from what has been said that the bog itself should be kept as free as possible from all plants other than vines, certain grasses being especially objectionable because they are used by long-horned grasshoppers as places to lay their eggs.

Bogs so arranged could be kept completely safe at all times, and once properly laid out would require little outlay to keep them so. The question whether bogs should be kept wet or dry, whether there should be many or few ditches, and whether these should be deep or shallow need not be here considered at all. The dates of flowage and reflowage and other points of measurement by means of which control may be made effective have been already touched upon.

The important advantages are that neither insecticides nor spraying machinery would ever be required, and the insect problem would be reduced to the simplest possible terms.

FARMERS' BULLETINS.

The following is a list of the Farmers' Bulletins available for distribution, showing the number and title of each. Copies will be sent to any address on application to any Senator, Representative, or Delegate in Congress, or to the Secretary of Agriculture, Washington, D. C. The missing numbers have been discontinued, being superseded by later bulletins.

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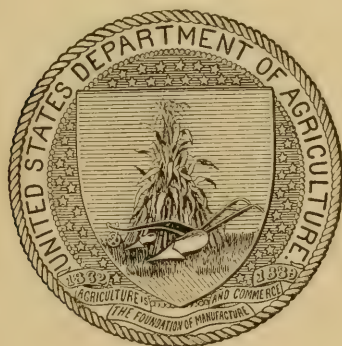
FARMERS' BULLETIN No. 189.

INFORMATION CONCERNING THE MEXICAN COTTON BOLL WEEVIL.

BY

W. D. HUNTER,

*Special Agent in Charge of Cotton Boll Weevil Investigations,
Division of Entomology.*



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1904.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., January 11, 1904.

SIR: I have the honor to transmit herewith an article entitled "Information Concerning the Mexican Cotton Boll Weevil," by Mr. W. D. Hunter, special agent of the Division of Entomology in charge of the cotton boll weevil investigations. Owing to the great importance of the subject and the urgent demand for all possible information before planting, I urge its immediate publication as a farmers' bulletin.

Respectfully,

L. O. HOWARD,
Entomologist.

Hon. JAMES WILSON,
Secretary of Agriculture.

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INFORMATION CONCERNING THE MEXICAN COTTON BOLL WEEVIL.

RECOMMENDATIONS.

The work of the Division of Entomology for several years has demonstrated that there is not even a remote probability that the boll weevil will ever be exterminated. Although the very large yields of cotton of former times may no longer be possible, it is nevertheless entirely feasible to produce cotton at a margin of profit that will compare favorably with that involved in the production of most of the staple crops of the United States by following what have become known generally as the cultural methods. These methods consist of the following changes and modifications of the system of cotton raising made necessary by the weevil. They were originally suggested by a careful study of the life history and habits of the pest, and naturally any improvements that may eventually be made will be the result of the continuation of that study. They have now been tested successfully on a large scale by the Division of Entomology, as well as by many planters, during two very unfavorable seasons. Of greatest advantage is the reducing of the numbers of the weevils by the destruction of the plants in the fall. The advantage thus gained is followed up by bending every effort toward procuring an early crop the following season.

(1) Plant early. If possible plant seed of the varieties known to mature early, or at least obtain seed from as far north as possible. It is much better to run the risk of replanting, which is not an expensive operation, than to have the crop delayed. The practice of some planters of making two plantings to avoid having all the work of chopping thrown into a short period is a very bad policy from the weevil standpoint.

Under identical conditions early cotton of improved varieties has invariably yielded from two to three times as much as native cotton under the same conditions, and in many cases much more. Planted at the same time, the early varieties begin to bloom from twelve to eighteen days sooner than native cotton.

Early planted fields of either native or improved varieties have almost invariably yielded twice as much as late planted ones.

The early varieties in general, having a small stalk and a short tap-root, are adapted only for rich soil. They also fail to grow well in the

very light, drifting sandy loams of many of the river valleys of Texas which, in long seasons before the advent of the boll weevil, often produced the largest yields. In these situations early varieties will yield but little more than native cotton.

(2) Cultivate the fields thoroughly. The principal benefit in this comes from the influence that such a practice has upon the constant growth and consequent early maturity of the crop. Very few weevils are killed by cultivation. Much of the benefit of early planting is lost unless it is followed by thorough cultivation. In case of unavoidably delayed planting, the best course for the planter to pursue is to cultivate the fields in the most thorough manner possible. Three choppings and five plowings constitute as thorough a system of cultivation as is necessary in cases where the land has previously been kept reasonably clear.

(3) Plant the rows as far apart as experience with the land indicates is feasible, and thin out the plants in the rows thoroughly. On land which in normal seasons will produce from 35 to 40 bushels of corn the rows should be 5 feet apart. Even on poor soil it is doubtful if the distance should ever be less than 4 feet.

(4) Destroy, by plowing up, windrowing, and burning, all the cotton stalks in the fields as soon as the weevils become so numerous that practically all the fruit is being punctured. This will generally not be later than the first week in October. Merely cutting off the stalks by means of the triangular implement used for that purpose throughout the South is by no means as effective as plowing, because the stumps remaining give rise to sprouts which furnish food until late in the season to many weevils that would otherwise starve. The plowing, moreover, serves to place the ground in better condition for early planting the following spring. In some cases turning cattle into the fields is advisable. Aside from amounting to a practical destruction of the plants, grazing of the cotton fields furnishes considerable forage at a time when it is generally much in demand. Nevertheless, cattle should never be turned into cotton fields in which Johnson grass has become started.

Recommendations 1, 2, and 3 are all aimed toward avoiding damage by hastening the maturity of the plants and do not involve the actual destruction of the weevils. Recommendation 4, however, reduces the numbers of the pests by destroying the very great proportion developing late in the fall and is consequently directly remedial.

(5) It is known that at present fertilizers are not used to any considerable extent in cotton producing in Texas. There is, nevertheless, no doubt that they should be; not that the land is poor, but that earlier crops may be procured. At present it is sufficient to call attention to the fact that it has been the uniform experience of experiment stations and planters in the eastern part of the belt that certain fertilizers, especially those involving a large percentage of phosphoric acid, have a strong tendency towards hastening the maturity of the plants.

INTRODUCTORY.

It is not probable that there will ever be a more generally unfavorable year for cotton culture in the United States than that of 1903. Toward the close of the preceding year (1902) the Bureau of Statistics of the United States Department of Agriculture reported a condition of the cotton crop, resulting from insect ravages and unfavorable climatic conditions in Texas, little short of disastrous. But the season of 1903 has had as many unfavorable features, and in addition the drawback that planting was unavoidably uniformly thrown from four to six weeks late. This was especially unfortunate, as early planting is the most important step in avoiding damage by the weevil. Many planters were unable to put in one-half of their normal cotton acreage. The late planting season was followed by very irregular rains. As a rule severe droughts alternated with heavy rains. The result would have been to cause a small crop regardless of damage by the boll weevil, and this was especially noticeable in central Texas. The experience of Mr. Harry Fields, a prominent planter of Robertson County, is typical of that of a great many planters in that part of the State. In 1902 on a certain cut of 180 acres 65 bales of cotton were produced. On the same land in 1903 only 15 bales were produced. These unfavorable conditions necessarily handicapped the work of the Division of Entomology, and in the experimental fields some points that would doubtless be perfectly evident under normal conditions were but little apparent; for instance, in many fields wide spacing of the rows was rendered fruitless, and some fields were so late that additional cultivation did not have the effect that it should. Nevertheless, the Division succeeded in proving by several striking illustrations that cotton may still be produced in Texas, and in not one of the experimental fields, aggregating 558 acres, did the crop fall much below the average in the United States before the weevil came into Texas—that is, about one-half bale to the acre—except in a few cases where there was a poor stand or the crop was damaged by floods. It should be understood, however, that this yield of about half a bale to the acre does not apply to the check fields, which were necessary in order to determine the results of the experiments. Even in the one case where the Division produced a bale to the acre, the adjoining check fields produced practically nothing. Some of the more noteworthy results of the work of the season that are unmistakable despite the unfavorable conditions have been selected for presentation on the following pages with matter relating to the methods pursued, as well as an account of some other matters—such as territory affected, the amount of damage, and the prospects—that are of particular interest at this time.

TERRITORY AFFECTED.

Up to the present time (January, 1904) the boll weevil has been found outside of the State of Texas in only three instances. One of these was at Audubon Park in the vicinity of New Orleans, where one of the fields of the Sugar Experiment Station at that place was found infested in August. The station authorities, under the direction of their entomologist, in a prompt and well-advised manner destroyed all the cotton by picking up the fallen fruit, uprooting and burning the plants, and subsequently flooding and plowing the land after it had been burned over. As there are no other cotton fields within 9 miles of Audubon Park and several examinations of the nearest ones failed to reveal any weevils, it is likely that the colony was completely exterminated. The two localities in Louisiana where the weevil is known to exist at present are in Sabine Parish, directly opposite to Shelby County, Tex. In both these cases only isolated fields are infested, and the circumstances indicate that the pest was brought from Texas in cotton seed or other cotton products. The Louisiana authorities are attempting to exterminate these colonies as they did that at Audubon Park.

The accompanying map shows the territory at present affected by the weevil in Texas and Louisiana (fig. 1).^a On the north it has been found in the vicinity of Sherman, only a few miles south of the Red River. The nearest approach to Shreveport is in Morris County, about 50 miles away. It should be observed, however, as indicated on the map, that in the region from about the latitude of Dallas to the Red River the pest is only scatteringly present and has caused no general damage. It will require about two years to reach sufficient numbers to reduce the normal production materially.

^aThe map is incorrect in regard to the exact location of the infested region in Louisiana. The shaded portion should include the western edge of Sabine instead of De Soto Parish.

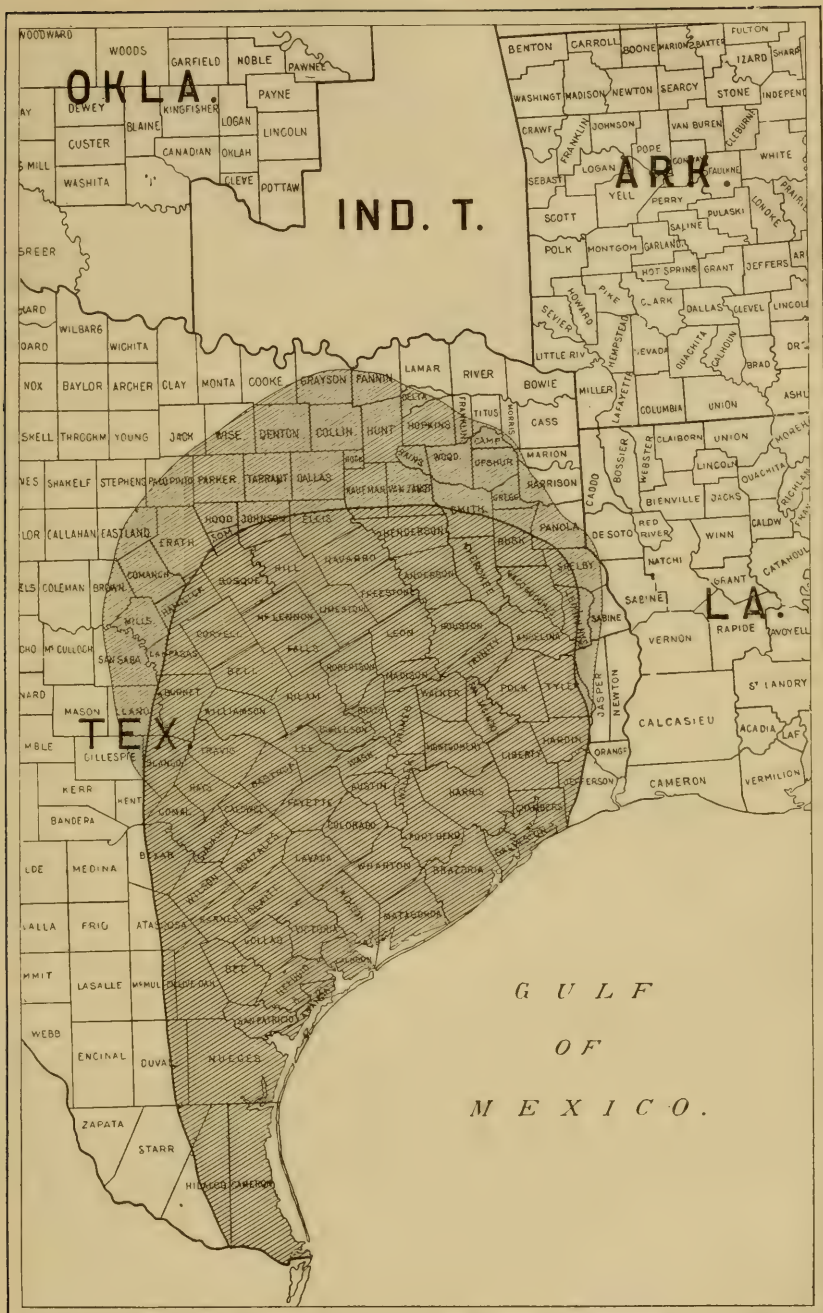


FIG. 1.—Map showing distribution of cotton boll weevil in the United States. The heavy line indicates the limit of the region in which the weevils have multiplied to such an extent as to be found in all cotton fields; the remainder of the shaded portion indicates the region in which isolated colonies are known to exist (original). See correction in footnote on opposite page.

AMOUNT OF DAMAGE.

Although many conditions make it very difficult to reduce the damage caused by the weevil to figures, it is believed that the following table presents a reasonably accurate estimate of the extent to which the pest affects the production of cotton for a few years subsequent to its advent:

Comparative estimate of amount of damage by cotton-boll weevil.

Typical counties in which weevil was not present in 1899, but was present in 1902.			Typical counties in which weevil was not present in either 1899 or 1902.		
County.	Product in commercial bales.		County.	Product in commercial bales.	
	1899.	1902.		1899.	1902.
Caldwell.....	47,473	23,133	Montague.....	15,064	16,981
Colorado.....	30,923	11,493	Cooke.....	11,905	11,012
Fayette.....	73,238	31,200	Grayson.....	40,871	54,087
Gonzales.....	44,131	25,351	Fannin.....	59,802	70,540
Grimes.....	26,541	12,135	Lamar.....	49,193	59,269
Lavaca.....	42,484	22,906	Wise.....	17,556	18,869
Montgomery.....	10,272	3,660	Denton.....	20,381	24,541
San Jacinto.....	8,826	3,044	Collin.....	49,077	47,344
Travis.....	60,078	28,382	Hunt.....	50,317	49,713
Wharton.....	27,383	12,870	Delta.....	24,705	26,256
Total.....	371,349	174,174	Total.....	338,871	378,612
Decrease.....per cent.....		53	Increase.....per cent.....		11

The first section of the above table shows a comparison of the production in ten counties in Texas in 1899, when the weevil had scarcely reached them, and in 1902, when it had multiplied to such an extent as to be found in great numbers in practically all cotton fields. These two years were selected for comparison for the reason that they were practically identical in amount and distribution of rainfall and in other essential crop conditions. The second part of the table gives a comparison of the production during the same years in ten other leading counties situated so far north that the weevil had not affected them in either of the two years used for comparison. It will be noticed that while in the counties of the first series there had been a decrease in production of 53 per cent, in the counties of the second series there had been an increase of 11 per cent. There seems to be no reason why the cotton production of the counties of the first series would not have increased at about the same rate as was the case in those of the second series had it not been for the damage caused by the weevil. This makes it fair, it is believed, to conclude that the approximate damage caused by the insect was the sum of the decrease in one case and the increase in the other, or about 64 per cent. There are two sources of possible error in these figures. One is in the likelihood of a change in acreage between 1899 and 1902 that may not have affected the two regions alike, and the other is in the probability that the two seasons were not exactly similar. In relation to the first point it must be stated that increases in acreage are generally the result of conditions of the markets that would affect the whole State

alike, and that if there were any increase in these years it would probably have been very much alike in either case. As to the possibility of an appreciable difference in the seasons, it must be stated that the two regions are comparatively close together, and that a careful examination of the records shows that they were remarkably alike in all important respects. Nevertheless, it is the tendency of planters, as soon as the weevil becomes a serious menace, to devote more of their land to other crops. Accurate figures on this point are not obtainable, but on the whole an allowance of a reduction of this kind that would account for 10 per cent decrease in production would be ample. It therefore seems to the writer that a figure in the neighborhood of 50 per cent represents a very fair approximate estimate of the loss.

In this connection it is interesting to note that the statistics drawn from acreage and production to which the writer referred in a previous article (Yearbook, Department of Agriculture, 1901, p. 373), indicating that the boll weevil causes the amount of land required to produce a bale to be practically doubled, bear out the foregoing conclusions.

Upon the foregoing basis, during the past season the boll weevil has caused the planters of the State of Texas a loss of fully \$15,000,000, and this estimate agrees rather well with the estimates made in other ways by the more conservative cotton statisticians.

Many conditions of climate and plantation practice in the eastern portion of the cotton belt indicate that the weevil problem will eventually be as serious there as it now is in Texas. With Mr. Richard H. Edmunds's estimate that the normal cotton crop of the United States represents a value of \$500,000,000, the possible ultimate damage when the pest has spread over the belt would be in the neighborhood of \$250,000,000 annually, provided no means of avoiding damage were adopted.

There are conditions at work that seem to indicate that planters in the weevil region are gradually adopting changes in their system of producing the staple that have a tendency to avert damage. No one who travels through the southern counties of Texas or who carefully examines the statistics pertaining to that region can avoid the conclusion that the planters will continue to produce cotton profitably and with a comparatively immaterial decrease. For instance, the following table shows to what extent cotton has been raised in Victoria County since the weevil reached it:

Cotton production in Victoria County, Tex., in equivalents of 500-pound bales.

Year.	Bales.	Year.	Bales.
1894	6,895	1899	5,547
1895	4,404	1900	11,956
1896	9,796	1901	9,060
1897	7,748	1902	9,236
1898	7,006		

PLAN OF THE INVESTIGATIONS OF THE DIVISION OF ENTOMOLOGY.

The work of the Division of Entomology consists of field experiments and laboratory investigations. Four entomologists were engaged in the work in Texas, and one conducted studies in Cuba. The field work of the season of 1903 comprised considerable tracts of cotton grown in such a manner as to constitute demonstrations of the means necessary to produce the staple profitably in spite of the weevil. These experimental fields amounted to 558 acres located at seven different points representing the five regions in Texas which by reasons of variations in climate and soil constitute as many distinct cotton districts. One hundred and fifty-six acres at Victoria and Wharton together represented typical situations in the river valleys of the coast belt, where the occurrence of volunteer cotton is rather normal, and by furnishing early food for the pests in the spring involves a feature that is lacking elsewhere. Twelve acres at San Antonio represented the problem in the case of cotton grown under irrigation, where the work of the season has shown that it is particularly easy to control the pest. At Austin 100 acres were devoted to experiments in the typical high black prairie region, which includes the most productive counties in Texas. At Calvert, in the Brazos River Valley, 200 acres, the largest body of experimental cotton at one place, represented the river valley region of central Texas, where the low and moist situation, presence of timber, defective labor system, and almost exclusive production of cotton together make what will be the most serious weevil region in the United States until the Yazoo Valley in Mississippi shall become invaded. At Hetty and Willspoint 40 and 50 acres, respectively, represented the river valley region of north Texas and the high prairie country of that portion of the State. Under a contract representative planters at the several places undertook to prepare the land, plant and care for the crop in every detail exactly in accordance with the directions of the Division of Entomology. The system gives the Division practically complete charge of large tracts of cotton without involving the expense of renting the land and working the crop, and has been found to be a most satisfactory method of conducting such field work on a large scale. In these fields every expedient that has been found to be useful in avoiding damage by the weevil was tried. These include early varieties, different methods of planting, special cultivation, rotation, fall destruction of the plants in various ways, and many others. The most difficult feature in work of this kind is in the interpretation of the results and in attributing to each factor in the process the effect that belongs to it. To assist as much as possible in this matter, wherever a field was treated in any manner out of the ordinary, another one alongside of it, as a check, was given only the

ordinary attention. The accompanying plan (fig. 2) will illustrate the method of one of these experiments located near Austin upon the plantation of Mr. Jefferson Johnson. The field contained 100 acres and was divided into 16 blocks containing $6\frac{1}{4}$ acres each, separated by rows of Milo maize to avoid confusion in picking.

It will be seen that a typical early variety, the King, is contrasted with the ordinary cotton of the region. Each one of the plats of the King cotton serves as a check upon each of the plats of that variety as well as upon a plat of the same size of native cotton treated in exactly the same manner. It thus becomes possible to estimate with reasonable accuracy the effect of select seed, early planting, wide rows, and thorough cultivation.

The work of the Division of Entomology during the season of 1902 demonstrated that it is possible to produce cotton profitably in spite of the boll weevil; the work of the season of 1903 showed this again under different conditions of climate and soil on a larger scale, and in addition furnished practical demonstrations of the success of the recommendations of the Division to planters at six different points in the State. For example, in a 25-acre experimental field located at Wharton a bale to the acre was picked. This experiment was performed upon land that had been in cotton continuously for five years, and the weevil had been present in the neighborhood for eight years. As the average crop of cotton in the United States has been 1 bale to 2.3 acres, and as the average production the present year in Wharton County was probably in the neighborhood of 1 bale to 7 or 8 acres, this experiment was naturally of considerable importance as a demonstration to the people of that region.

As will always be the case in formulating a plan for avoiding damage by an insect, the basis for what are now known as the cultural methods of combating the boll weevil was the result of careful studies of its life history and habits. In the hope of discovering points hitherto unnoticed that might be of use in fighting the pest, the investigation of every feature of the life history of the weevil was continued in the laboratory at Victoria. The observations and experiments made here during the season of 1903, as well as the season of 1902, will result in the publication in the near future of an account of the biology of the weevil at least as complete, it is believed, as that of any North American species. At the same time many tests of poisons and spraying mixtures were made in the laboratory whenever samples of the various compounds that had been widely advertised in Texas could be obtained. As would be supposed, none of these preparations were found to be effective, and reports to that effect made to correspondents doubtless prevented some useless expenditure of money.

The cooperation with the commission of the Mexican Government

1 6.25 A. KING. EARLY. ROWS 3½ FEET. THOROUGH CULTIVATION.
2 6.25 A. KING. EARLY. ROWS 3½ FEET. LESS THOROUGH CULTIVATION.
3 6.25 A. KING. EARLY. ROWS 5 FEET. THOROUGH CULTIVATION.
4 6.25 A. KING. EARLY. ROWS 5 FEET. LESS THOROUGH CULTIVATION.
5 6.25 A. KING. LATE. ROWS 3½ FEET. THOROUGH CULTIVATION.
6 6.25 A. KING. LATE. ROWS 3½ FEET. LESS THOROUGH CULTIVATION.
7 6.25 A. KING. LATE. ROWS 5 FEET. THOROUGH CULTIVATION.
8 6.25 A. KING. LATE. ROWS 5 FEET. LESS THOROUGH CULTIVATION.
9 6.25 A. NATIVE. EARLY. ROWS 3½ FEET. THOROUGH CULTIVATION.
10 6.25 A. NATIVE. EARLY. ROWS 3½ FEET. LESS THOROUGH CULTIVATION.
11 6.25 A. NATIVE. EARLY. ROWS 5 FEET. THOROUGH CULTIVATION.
12 6.25 A. NATIVE. EARLY. ROWS 5 FEET. LESS THOROUGH CULTIVATION.
13 6.25 A. NATIVE. LATE. ROWS 3½ FEET. THOROUGH CULTIVATION.
14 6.25 A. NATIVE. LATE. ROWS 3½ FEET. LESS THOROUGH CULTIVATION.
15 6.25 A. NATIVE. LATE. ROWS 5 FEET. THOROUGH CULTIVATION.
16 6.25 A. NATIVE. LATE. ROWS 5 FEET. LESS THOROUGH CULTIVATION.

FIG. 2.—Plan of experimental field, Travis County, plantation of Mr. Jefferson Johnson.

engaged in an investigation of the weevil in that country, which was begun the preceding year, was continued. Much material, such as parasites, was exchanged, and each investigation was kept informed of the progress of the other.

In addition to the work in Texas Mr. E. A. Schwarz spent several months of the past year in Cuba, studying the manner in which natural conditions, whether of parasites, diseases, climatic conditions, or of the presence of a degree of resistance on the part of the plant, controlled the insect where it has existed as an enemy of cotton for a much longer period than in the United States. He found what appears to be the original food plant in the "algodon de riñon" or kidney cotton of that island. Nevertheless, he failed to discover any parasites at all, and did not succeed in finding any important tendency toward immunity on the part of the five distinct varieties studied. Through the interest and courtesy of Mr. Edward Ferrer, the proprietor of a large estate nearer Cayamas, Mr. Schwarz arranged to have several wild varieties planted on land where a seriously infested field had grown the year before. Mr. Ferrer has very recently reported that none of these varieties have exhibited the slightest tendency toward immunity, the squares of the native varieties being punctured as freely by the weevils as those of the ordinary American cotton. The experiment thus bears out the previously published conclusions of the investigators of the Division of Entomology, based upon observations in Mexico and Central America as well as in Texas, that apparently no known variety or strain of cotton is distasteful to the weevil. However, the importance of a continuation of this line of the work is evident.

SOME OF THE RESULTS OF THE FIELD WORK.

Upon the plantation of Mr. A. P. Borden, to which reference has already been made, the Division of Entomology had a 100-acre field planted in such a manner as to show the value of several methods of treatment. The experiment was purposely located upon land that had been in cotton for a number of years, and in a situation adjoining the river, where the weevil damage is generally greatest. As will be seen in the accompanying diagram (fig. 3), the field was divided into four plats of 25 acres each. All the plats were planted with the seed of a typical early maturing variety. Two of these plats were planted as early as possible, and one of these was given more thorough cultivation than the other. The two remaining plats were planted late, and the same difference in cultivation applied. The results were as follows:

Early King cotton with thorough cultivation produced 459 pounds of lint to the acre.

Early King cotton with less thorough cultivation produced 250 pounds of lint to the acre.

Late cotton, regardless of cultivation, produced nothing.

There are two respects in which the results of this experiment would probably have been different under different climatic conditions. In another season there would probably not be as great a difference in yield, due to additional cultivation, and, moreover, there would doubtless be some cotton produced on the other plats in spite of

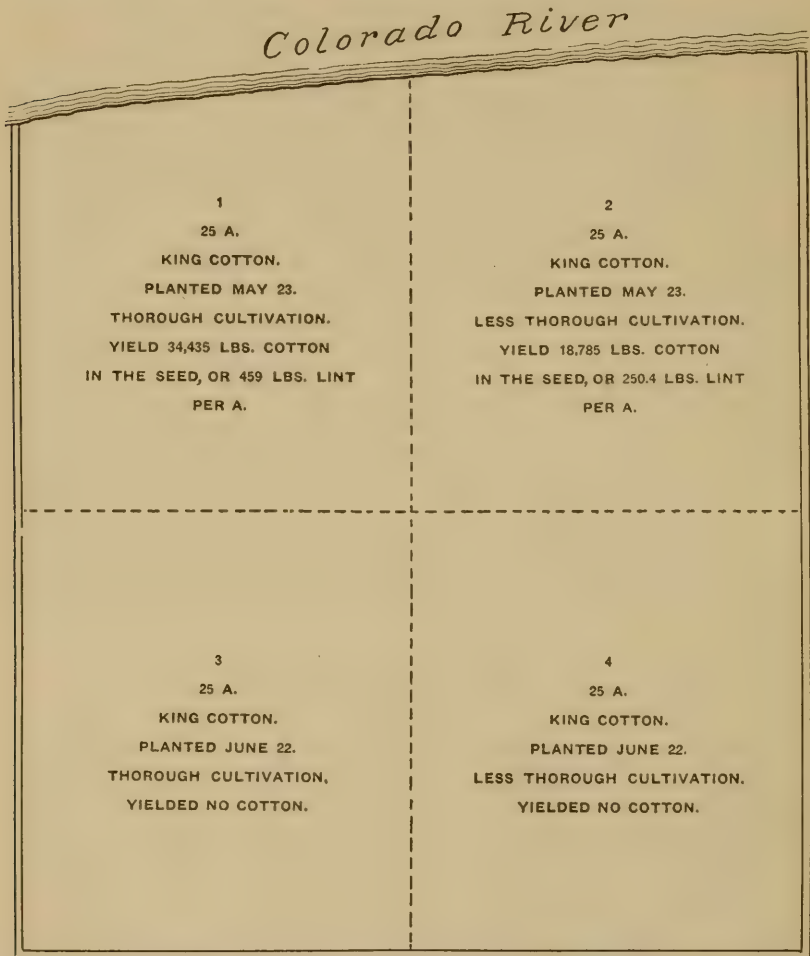


FIG. 3.—Plan of experiment upon plantation of Mr. A. P. Borden, Wharton County, Texas.

the late planting. Nevertheless, experiments at other points show that, with some variation that is always associated with the seasons, the results of this experiment as regards the advantage of early planting and thorough cultivation will apply to practically all situations.

An examination of the profit on the 100 acres covered by this experiment proves to be interesting. The cotton was sold in the seed at \$3.25

per 100 pounds. The cost of producing it, including such items as taxes on the land, wear and tear of machinery, and all the other operations, from breaking the land to ginning the product, computed for the lint, was $4\frac{1}{4}$ cents per pound. There was consequently a margin of profit in plat 1 of \$25.24 per acre; on plat 2, of \$13.79 per acre, or an average on the 50 acres of early cotton of \$19.51 per acre. Reckoning the loss incurred in working plats 3 and 4, which produced nothing, at \$6 per acre, there was nevertheless a net margin of profit on the 100 acres of \$6.76 per acre. A tabular statement of these results follows:

PLAT I.

Value of yield, 34,435 pounds in seed (11,475 pounds lint), at \$3.25 per 100 pounds.....	\$1, 119. 13
Cost of producing 11,475 pounds lint, at $4\frac{1}{4}$ cents per pound.....	487. 68
Net profit on 25 acres	631.45
Net profit per acre.....	25. 24

PLAT II.

Value of yield, 18,785 pounds in seed (6,250 pounds lint), at \$3.25 per 100 pounds.....	610. 51
Cost of producing 6,250 pounds lint, at $4\frac{1}{4}$ cents per pound.....	265. 62
Net profit on 25 acres	344. 89
Net profit per acre.....	13. 79

100 ACRES COVERED BY EXPERIMENT.

Value of yield, 53,220 pounds in seed, at \$3.25 per 100 pounds.....	1, 729. 65
Cost:	
Plat I	\$487. 68
Plat II	265. 62
Plats III and IV up to laying by, at \$6 per acre	300. 00
	1, 053. 30
Net profit on 100 acres	676. 35
Net profit per acre.....	6. 76

It may be added that the proprietor of the plantation upon which this work was conducted had 300 acres in improved cotton (not under contract with the Division of Entomology) upon which he made 209 bales. In 1902 on the same place he had about 700 acres in native cotton, but produced only 200 bales. This bears out the observation referred to in another place that the improved varieties may be depended upon to produce at least twice as much as the native plants under similar conditions.

A VARIETY TEST.

In order to ascertain the comparative value of several of the different varieties of cotton in avoiding damage by the boll weevil, eight more or less well-known varieties were planted in plats of 5 acres each

in a typical situation in the Brazos Valley near Calvert. The land had been in cotton for many years. The year before the plants were left standing until after frost, and consequently the weevils were everywhere abundant. The soil was uniform throughout, and all plats were cultivated by the negro tenants, who gave them the same attention that would be given any cotton grown in that locality. The native cotton was the ordinary cotton of the region. It has been planted and replanted there in many instances for as long as a quarter of a century. The variety is unknown, but it evidently has some relationship to the Texas Storm Proof group. Planting took place the first week in April. The following table shows the results of this experiment:

Yield of several varieties of cotton in experimental plats near Calvert, Tex.

Variety.	Yield per acre, cot- ton in seed.	Variety.	Yield per acre, cot- ton in seed.
	<i>Pounds.</i>		<i>Pounds.</i>
Herndon.....	801	Texas Bur.....	456
King.....	672	Shine.....	449
Dickson.....	590	Native.....	304
Hutchinson.....	573	Jones Improved.....	286

This test was a severe one, because exceptionally unfavorable local conditions made that particular region the most seriously damaged one in Texas. The production on the plantations of the neighborhood certainly did not average more than one-seventh of a bale to the acre. But, notwithstanding the disadvantage, it will be seen that two varieties, namely, the King and the Herndon, produced about a half a bale to the acre, which, at current prices, was quite profitable; while the native cotton produced one-fifth of a bale per acre, a yield from which, with the labor conditions of that locality, there could scarcely be any appreciable profit. The only variety which proved to be less productive than the native was the Jones Improved, in which the improvers have sacrificed earliness for largeness of boll, productiveness, and strength of stalk. The variety would certainly be valuable if it were allowed to mature, but its lateness will always make it very undesirable in regions infested by the boll weevil.

EXPERIMENT SHOWING DAMAGE RESULTING FROM FAVORABLE HIBERNATING QUARTERS.

This experiment was performed in Travis County, Tex. The accompanying diagram (fig. 4) will make the details clear. Plats 2 and 3 were in sorghum the preceding year. The stubble was not removed until shortly before planting time. Plats 1 and 2 were in cotton the year before, and the plants were left standing until December. The soil was uniform throughout, and all four plots were cultivated exactly

alike. The increased number of weevils in the plots on the stubble land was evident early in the season. On August 5, when the plants were beginning to put on squares abundantly, it was found that 43 per cent of the squares were infested in plats 2 and 3, while 36 per cent

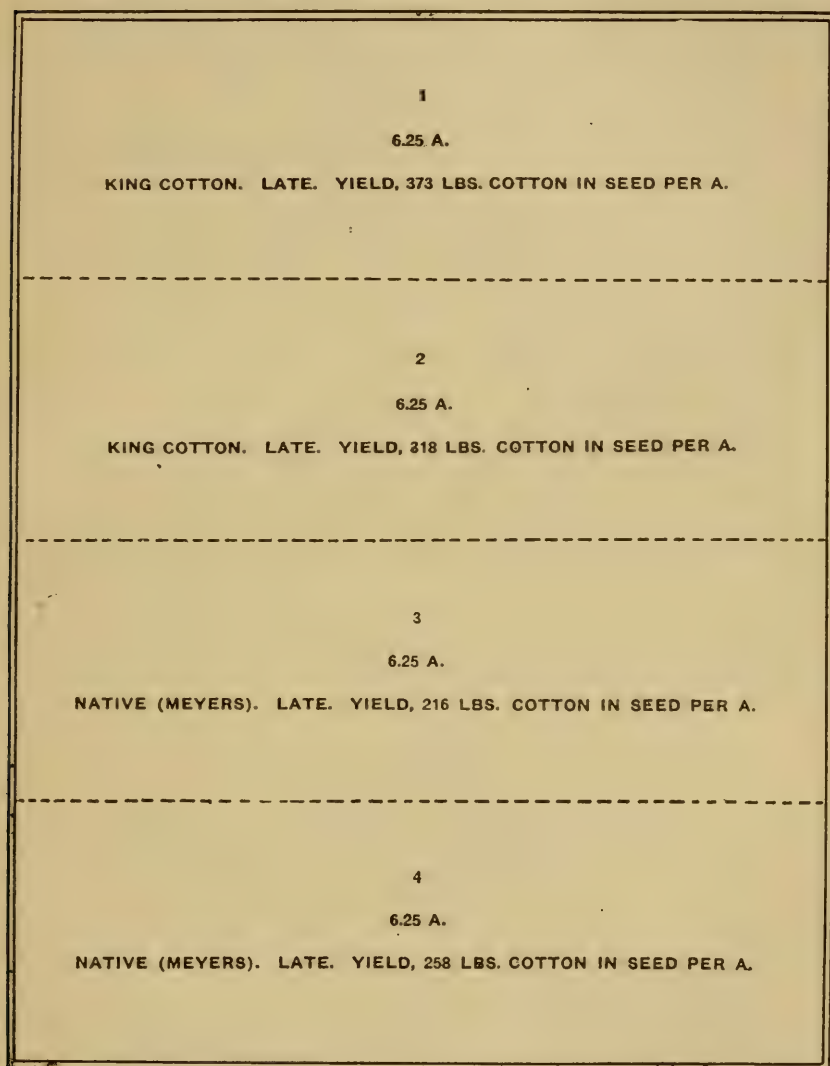


FIG. 4.—Experiment showing damage resulting from favorable hibernating quarters.

in plat 1 and 33 per cent in plat 4 were infested. This greater damage in the case of the cotton planted on the sorghum stubble continued uniformly until late in the season, when a natural overflow of weevils from plats 2 and 3 caused the adjoining plats to be affected to about the same extent. As will be seen from the diagram, the fact

that the weevils did not reach the plats removed from the sorghum until late caused the production in the case of both King and native cotton to be increased at about the same ratio.

This experiment demonstrates to what extent weevil damage may be expected when cotton is planted where conditions have been favorable for hibernation. It explains the fact of greater damage in certain localities that many planters have observed. The obvious conclusion is that cotton should not be planted upon land which was in sorghum the preceding year. In case it is impossible or inexpedient to avoid such planting, the best that can be done would be to plow under the stubble as deeply as possible early in the fall. It should be mentioned that sorghum stubble is only an example of many situations favorable for the hibernation of the weevil. Any portion of any crop or weeds or grass left upon the ground not only serves in itself to protect the pest during the winter, but in addition catches *débris* carried by the winds, and thus causes the protection to be all the more complete. Clean farming, by which is meant the killing of all weeds by thorough cultivation, and the removal of all portions of the crop from the land by burning or plowing under as soon as possible after the time of harvesting, is nearly as important in the case of a sorghum or corn field that is to be put in cotton the following season, provided there are cotton fields adjoining, as it will be subsequently in the cotton field.

The foregoing experiment incidentally shows a rather striking superiority of an early variety over a late one, even under the most unfavorable conditions of lateness of planting and abundance of weevils. The two fields of the early variety together yielded nearly 35 per cent more cotton than the two fields of the native variety together.

PROSPECTS.

The steady extension of the territory affected by the weevil from year to year, until the northern boundary is far north of the center of cotton production in the United States, has convinced all observers that it will eventually be distributed all over the cotton belt. In ten years it has gradually advanced a distance of about 500 miles, and will undoubtedly invade new territory at about the same rate. It is not at all likely that legal restrictions of any kind would prevent or materially hinder this spread. The slowness of the progress up to the present time indicates that the principal means of spreading are only natural ones, like the winds and a simple overflow from field to field, and that the artificial agencies like transportation in seed or in other commodities are comparatively unimportant; otherwise, with the extensive shipping from Texas, instead of being confined to that State as at present, the pest would now be found in many localities throughout the South. Legal restrictions could only be directed against these

artificial means of distribution and would be expensive and difficult to enforce. The benefits could be no more than temporary, and might be more than counterbalanced by the damage resulting from interference with shipping. It seems that the best that planters in any uninfested locality can do to prevent the incoming of the weevils would be only palliative, and would consist in avoiding the procurement of seed from localities that are known to be infested, and also in avoiding as much as possible the hauling of hulls and other seed products in which the weevils are more or less likely to be found from the mills to the vicinity of cotton fields.

Unfortunately, it must be confessed that during the time the weevil has been in Texas it has displayed no tendency toward dying out. In south Texas it is practically as troublesome now, except in so far as it is affected by changes in managing the crop, as it was in 1895; and in Mexico, where it has existed for a much longer period, it is apparently as plentiful as ever. The investigators of the Division of Entomology have made an especially careful study of all the features of the life history of the pest that would throw any light upon the question of whether it will, like many other injurious species, die down and gradually become a much less important enemy to the plant than now. In this work attention has been paid to parasites and diseases, and an exhaustive study has been made of temperature conditions in connection with several months' work on the hibernation of the pest, at Victoria, by Mr. Schwarz. Likewise the accounts of related species both in this country and in Europe have been used for comparison. It is true that it is a well-known general observation that many species of insects, upon reaching a new region, are stimulated by an abundance of food and the absence of the conditions that might have held them measureably in check elsewhere to a more rapid multiplication than normal. In order to avoid errors from this source as much as possible the laboratory of the investigation was located in the cotton-producing portion of the southern part of Texas, where the infestation has been longest. Nevertheless, all the observations and experiments have failed to reveal any factors that show any indication of causing the pest to become much less destructive than now. After ten years, during which it has maintained practically constant numbers, there seems but little risk in the statement that the pest will probably always be as destructive in a series of years as it has been in Texas since 1894. However, planters will undoubtedly gradually adopt new methods in raising cotton, so that the damage in any given locality will not be as noticeable as it was in the beginning, and climatic conditions will undoubtedly cause temporary diminution of the numbers of the pest in certain localities. In Texas these conditions have given rise almost every year to the supposition on the part of some planters

that the insects have died out, while the experience of the following season has invariably destroyed their hopes. In general, wet winters and dry-growing seasons are unfavorable for the weevil. When a series of years involving such conditions is followed by a season of less than normal rainfall, the weevil will be temporarily a comparatively unimportant factor, although its presence will undoubtedly always prevent the maturity of a fall crop. The most disastrous seasons will be those like the past season (1903), in which the rainfall is excessive and the planting time unavoidably late.

WILL THE WEEVIL REACH OTHER COTTON-PRODUCING COUNTRIES?

The fact that several European governments are sending agents to this country to procure seed to be used in experiments in producing the staple in their colonies lends some interest to speculation as to the probability that the weevil may soon be carried to remote portions of the globe. Although the insect does not, except accidentally, hibernate within the hull of the seed, every seed house attached to a gin in the infested territory harbors many that are picked accidentally and brought in from the fields in the seed cotton. In case the seed happens to be sacked or even shipped in bulk there is nothing whatever to prevent the weevils from being carried long distances on ship-board. When thus transported the indications are that they would be able to adapt themselves successfully to climatic conditions anywhere that cotton may be grown, unless possibly in a region of great elevation, like that of the Laguna district in Mexico. Although the writer is informed that the agents engaged in obtaining American seed are carefully avoiding the infested portions of Texas, in view of the foregoing and of the fact that the pest is spreading rapidly, the probability that it may eventually be carried to West Africa or elsewhere is not at all remote. This could be easily avoided by fumigation of the seed or by leaving it sacked in storage rooms isolated from new cotton for a year previous to shipment.

DESCRIPTION OF WEEVIL.

Every intelligent planter in the weevil-infested area is able to determine the presence of the pest by its appearance and the evidence of its work, but planters who have never seen it are often in doubt as to whether some insect damaging the crop is the boll weevil or not, as well as to whether flaring and falling of the fruit is caused by some unseen insect pest or by climatic conditions. For the benefit of Texas planters outside of the weevil territory at present, as well as planters in other States where the pests are more or less likely to be found at any time, the following description of the insect and its work are

given. It is believed that this will enable any planter to determine whether or not the pest is at work in his fields, and to take the necessary steps to fight it at the earliest possible moment.

The adult weevil averages about one-quarter of an inch in length,



FIG. 5.—Cotton boll weevil: *a*, beetle, from above; *b*, same from side—about five times natural size (original).

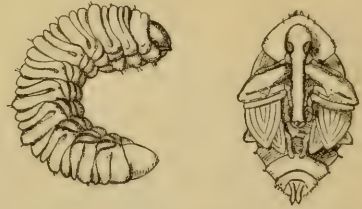


FIG. 6.—Cotton boll weevil: larva at left, pupa at right—about five times natural size (original).

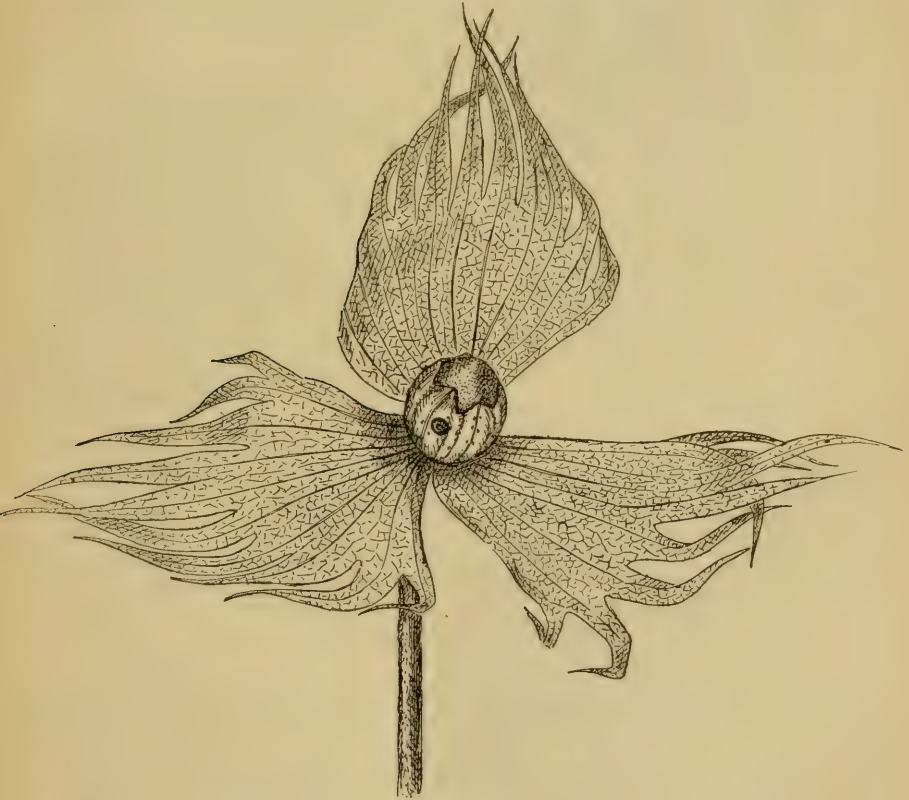


FIG. 7.—Cotton square showing egg puncture of boll weevil—natural size (original).

and has a beak about one-half the length of the body. It is of grayish or reddish-brown color. Its general appearance will be understood

from fig. 5. The insect exists in four stages—egg, larva, pupa, and adult (fig. 6). All the stages except the last occur only inside of the cotton square or boll. The egg is deposited by the female weevil in a cavity formed by eating into the fruit of the plant (fig. 7). It hatches, under normal conditions, in two or three days, and the grub immediately begins to feed. In from seven to twelve days the larva or grub passes into the pupal or quiet stage, corresponding to the cocoon of the silkworm.



FIG. 8—Cotton square showing boll weevil larva in position—natural size (original).

This stage lasts from three to five days. Then the adult weevil issues, and in about seven days begins the production of another generation. Climatic conditions cause considerable variation, but on an average it requires from two to three weeks for a weevil to develop from the egg to the adult.

The plainest indication of the presence of the weevil in a cotton field is in the flaring (fig. 8) and falling of the squares or forms, which take place, in general, within a day or two after the egg is deposited. However, as all planters are aware, heavy rains after

drought, as well as some other climatic conditions, have the same effect upon the plants. If the planter should observe an unusual shedding of the fruit, he may easily determine the cause by gathering a few of the fallen squares. If upon cutting open these squares he finds a small, whitish, curved grub, there is but little doubt that the cause of the trouble is the boll weevil. The specimen should then be sent to an entomologist for final determination.

LEGAL RESTRICTIONS CONCERNING SHIPMENT OF INFESTED COTTON SEED.

A realization of the damage likely to be caused to a most important crop by the introduction of the weevil into several States has led to the legal restrictions that are noted below. It will be seen that four

States, namely, Alabama, Georgia, North Carolina, and Louisiana, have very definite legislation on this matter, while one other, Mississippi, is about to enact similar regulations. For the purpose of delaying the progress of the boll weevil as well as for application to other injurious insects and plant diseases that may appear, it is recommended that a law similar to that in force in Georgia and Louisiana be enacted in all other Southern States.

ALABAMA.

AN ACT to prevent and prohibit the importation of seed from cotton affected with the Texas boll weevil.

SECTION 1. *Be it enacted by the legislature of Alabama,* That no person shall import or bring into the State of Alabama any seed from any cotton affected with what is known as the Texas boll weevil, nor the seed from any cotton from any place where the cotton has been affected with said boll weevil.

SECTION 2. Any person who violates the provisions of section 1 of this act shall be guilty of a misdemeanor, and on conviction shall be fined not less than ten dollars (\$10) and not more than five hundred dollars (\$500).

(H. 877, No. 559, approved Oct. 6, 1903.)

GEORGIA.

The crop-pest law of Georgia creates a board of entomology, and gives this board the power to enact and enforce such regulations as it may deem necessary to prevent the introduction or dissemination of seriously injurious crop pests or diseases. In accordance with this law the board has from time to time revised its regulations and has adopted new ones as circumstances have warranted. Under date of August 28, 1903, the State board of entomology adopted the following regulation with reference to the cotton boll weevil:

It shall be unlawful for any firm, person, or corporation to bring into the State of Georgia, or to have in possession for any purpose, any living Mexican boll weevil or any cotton bolls, squares, plants, or seed containing the adult, pupal, larval, or egg stage of the Mexican boll weevil.

No cotton seed grown in the States of Texas or Louisiana or consigned from points in those States shall be shipped into the State of Georgia without being accompanied by a certificate signed by a duly authorized State or Government entomologist stating that said cotton seed has been fumigated in such manner as to kill any boll weevils, larva, or pupa which may be contained therein.

NORTH CAROLINA.

The State of North Carolina has taken no legal measures to prevent the introduction of the boll weevil beyond the enactment of the crop-pest law which was passed in 1897. This law gives the crop-pest commission specific powers which may be applied to the boll weevil as they have been applied to various other insects. Following are the essential points in the law: The commission is given authority to make regulations for its own government, as well as such as may be requisite

for carrying out the provisions of the act which is entitled "An act to prevent the introduction and dissemination of dangerous insect, fungous, and weed pests of crops." The commission may also adopt regulations not inconsistent with the laws and constitution of North Carolina and the United States for preventing the introduction of injurious crop pests from without the State, and for governing common carriers in transporting plants liable to harbor such pests to and from the State, and such regulations shall have the force of law. When the crop commission has reason to suspect that any pest listed by them as injurious exists in any county of the State, they are required to cause such suspicion to be verified by a person competent to determine the specific identity of the pest, and if such suspicion proves founded upon fact, is further required to appoint for a designated time and duty a competent person for their agent to inspect such infested premises and to take such measures for treating them as the commission may direct. Anyone who shall seek to prevent inspection or who shall otherwise interfere with the operations of the commission in the performance of its duties shall upon conviction be fined not less than \$5 nor more than \$50 for each offense, or may be imprisoned for not less than ten nor more than thirty days.

(Chapter 264, Laws of 1897, ratified March 5, 1897.)

MISSISSIPPI.

At present the State of Mississippi has enacted no special legislation against the boll weevil; however, the legislature is now (January, 1904) in session and some provision similar to those in force in other States will probably be made.

LOUISIANA.

A recent special session of the legislature created a crop-pest commission that is charged with the formulation of such regulations as seem to be necessary in order to prevent a further advance of the boll weevil in the cotton fields. This commission, consisting of the State commissioner of agriculture, the director of the experiment station, the State entomologist, and two practical farmers, is now (January) in session. It is empowered to deal with all fruit and crop pests and is authorized to prohibit the shipment into the State of any cotton seed or other farm product from any region known to be infested by the weevil, except under such rules and regulations as it may promulgate. The act prohibits bringing into the State or having in possession any live weevils, under a penalty of not less than \$25 nor more than \$100, or imprisonment for not less than ten days or more than six months. Similar penalties apply to violations of any rules the commission may establish.

(Act No. 6, approved December 15, 1903.)

WARNING.

As a result of the recommendations of the Division of Entomology in regard to planting the seed of early varieties of cotton, which have been emphasized repeatedly by the executive committee of the Dallas Boll Weevil Convention and through other channels, there has been a sudden and enormous demand for special seed. In fact the demand in many cases has exceeded the supply. The result has been to inflate the prices of the seed of certain varieties and, more unfortunately, to cause unscrupulous persons to attempt to dispose of common seed from various localities as that of the early maturing varieties. This matter has gained such headway that it has been considered necessary that this warning be issued to Texas cotton planters. The cotton seed known as "run of the gin seed" from the eastern portion of the belt, though likely to be somewhat better than native seed on account of its more northern origin, is nevertheless almost certain to prove a disappointment to the purchaser. In comparison with the seed of select varieties it is not worth the price that is being charged for it. Planters who have occasion to obtain cotton seed should procure it in all cases where practicable through reputable seed houses, and in no case should seed be accepted without a guaranty as to its character. It is known of course that such a guaranty would be a recourse of doubtful legal value, but the moral effect of it at least would doubtless serve to protect the planter against fraud.

FARMERS' BULLETINS.

The following is a list of the Farmers' Bulletins available for distribution, showing the number, title, and size in pages of each. Copies will be sent to any address on application to any Senator, Representative, or Delegate in Congress, or to the Secretary of Agriculture, Washington, D. C. The missing numbers have been discontinued, being superseded by later bulletins.

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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 191.

THE COTTON BOLLWORM:

AN ACCOUNT OF THE INSECT, WITH RESULTS OF
EXPERIMENTS IN 1903.

BY

A. L. QUAINANCE,

Agent in Charge of Cotton Bollworm Investigations.



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1904.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., January 18, 1904.

SIR: I have the honor to transmit herewith the manuscript of an account of the cotton bollworm, based on investigations conducted during the year 1903, according to special Congressional appropriation made for the purpose, and prepared by Mr. A. L. Quaintance, agent in charge of cotton bollworm investigations. The bollworm is one of the most destructive insects of the United States, and, as the information furnished in this article is confidently believed to be of much value to cotton growers, it is urged that it be given immediate publication.

Respectfully,

L. O. HOWARD,
Entomologist.

HON. JAMES WILSON,
Secretary of Agriculture.

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THE COTTON BOLLWORM.

INTRODUCTORY.

The so-called bollworm, the larva of the moth *Heliothis armiger* Hbn., has long been known as an important enemy of cotton. As early as 1841 it was found in the cotton fields around Tallahassee, Fla., where, in the course of a few years, it became quite destructive. It was seriously injurious to cotton in Alabama in 1847, in Mississippi in 1850, and in Louisiana in 1867. By 1879 it had become the principal insect enemy of cotton in Texas, and at the present time ranks second in importance only to the Mexican cotton boll weevil.

This insect was early the subject of investigation by the General Government. In the Patent Office Agricultural Report for 1854, Townend Glover gave an excellent article on the bollworm, detailing the principal points in its natural history. The results of the work of the Division of Entomology and of the United States Entomological Commission on this insect from about 1878 to 1881 are displayed in Comstock's Report on Cotton Insects, and in the Fourth Report of the United States Entomological Commission by Professor Riley. A supplementary investigation of the bollworm was made by Professor Mally, under the direction of the Division of Entomology, in the early nineties, and the results are set forth in Bulletins 24 and 29 (old series), issued in 1891 and 1893 respectively. More recently (1897) an account of this species has been distributed in Farmers' Bulletin No. 47 (Insects Affecting the Cotton Plant), by Dr. L. O. Howard.

As a result of these several publications a knowledge of the bollworm's life and habits, and of the best methods to be employed in its control, has been quite widely disseminated. Nevertheless, little if any effort has been made by planters during the many years of bollworm injury to check its ravages, and, along with the increased cultivation of cotton from year to year, often to the exclusion of any other crop, the losses from this insect have tended to increase rather than to diminish.

The considerable injury done by the bollworm during the past two or three years, notably in certain portions of Texas, led to provision by Congress for a further investigation of this insect by the Division of Entomology, and the writer was detailed to the work in Texas.

Headquarters were established at Victoria, where office and other facilities were available in the laboratory of the force engaged in investigations relating to the cotton boll weevil. Such laboratory investigations as were possible were conducted, but special attention was given to field work, this being considered of more importance in view of the many facts already known about the life and habits of the bollworm. Through the cooperation of the agent charged with boll-weevil investigations, arrangements were made for the growing of cotton on the contract plan with planters at Calvert, Willspoint, and Hetty, Tex., including in all 140 acres. The locations chosen are fairly typical of the respective sections, and in two the bollworm had been especially destructive the year previous.

INJURY IN 1903.

Aside from certain isolated localities here and there in the cotton belt, bollworm injury during 1903 appears to have been confined mostly to Texas and to the southern portion of Indian Territory. The accompanying map (fig. 1), indicates the area most seriously ravaged in Texas. Injury was especially severe in some of the north Texas counties, as Fannin, Lamar, Delta, Hunt, Hopkins, Kaufman, and Van Zandt; and also in the central Texas counties, Navarro, Henderson, Limestone, Falls, Bell, and Robertson, the loss in each of these counties being variously estimated at from 20 to 60 per cent of the crop.

It is hard to arrive at even an approximate estimate of the loss, owing to the difficulty of securing trustworthy data. The tendency to exaggerate losses from insects is well known, as is also the tendency to attribute to insect depredations the disastrous effects which may result from changes in the weather or from other conditions. The shaded portion of the map includes the principal cotton-producing area of the State, from which, in 1902, came approximately three-fourths of the total cotton product of Texas. Throughout this area bollworm ravages were reported as more or less extensive in 1903. A conservative estimate of the injury, based on data secured from various sources and from personal observations, it is believed would be approximately 96,000 bales, which, at a valuation of \$50 per bale, would mean a loss of \$4,800,000. If to this amount be added the value of the cotton seed the total loss sustained would easily exceed \$5,000,000.

According to the estimate of Professor Mally, bollworm injury in Texas in 1902 amounted to approximately \$4,750,000, and the area most seriously ravaged coincides rather closely with that injured in 1903. It may also be said that the shaded portion of the map marks approximately the area of greatest corn production, and the simple rotation of corn with cotton, so largely practiced, has undoubtedly contributed to the seriousness of the bollworm situation at the present time.

DISTRIBUTION.

The bollworm has a world-wide distribution. It occurs throughout most of the United States, and is reported from many localities in Central and South America and the West Indies. It is recorded from various countries of Europe, as England, France, Germany, Spain,



FIG. 1.—Map of Texas, showing territory ravaged by bollworm in 1903.

and Russia; and also from the Canaries, Kongo, South Africa, New Zealand, Australia, Ceylon, Java, India, Japan, China, and Hawaii. It is not possible to determine the origin of the bollworm.

It is of interest to note that the species was described from Europe in 1796, while its first recorded occurrence in the United States was in 1841.

GENERAL APPEARANCE AND LIFE CYCLE.

Throughout this bulletin the common appellation of this insect in the cotton belt, namely, the bollworm, is adhered to. It need hardly be explained that the larva known variously as the budworm of corn, the tassel worm, corn earworm, and tomato fruitworm, is identical with the cotton bollworm.

The egg.—Bollworm eggs may easily be detected with the unaided eye, and may be most readily found on the fresh silk of corn. They are oval in shape, whitish or yellowish in color, and average in diameter about 0.45^{mm} to 0.5^{mm} . Examined under a hand lens, they are seen to be sculptured with polar ribs and cross furrows like those on the eggs producing the cotton caterpillar. The eggs of this latter species, however, are much flatter and greenish in color, and are, therefore, not likely to be confused with those of the species under consideration. The eggs of the bollworm hatch in from two and one-half to six days, depending on the temperature.

The larva.—The insect is most commonly known in this, the bollworm, stage. It is only during this larval existence that injury is inflicted. Newly hatched bollworms are very small and are usually quite overlooked by planters until they are of sufficient size to attack the buds, squares, and young bolls. As the larvæ grow, a remarkable diversity of color and markings may become apparent, ranging from whitish or greenish without decided markings of any kind, to individuals which are rose colored or almost black, with distinct spots and dorsal and lateral longitudinal stripes. This color variation has been the source of some confusion as to the identity of the larva, particularly when on other plants than cotton. The bollworm is a voracious feeder and grows rapidly, completing its growth during summer in from twelve to fifteen days. During the cool weather of spring and fall its rate of growth is much slower.

A full-grown larva measures from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in length. The body is stout and tapers slightly toward the head and caudal extremities. In the darker individuals the markings consist of a narrow, dorsal, central, longitudinal, black stripe, centered with a fine white line. On each side of the body, including the breathing pores, is a broad, whitish, lateral stripe, extending from the head to the last segment. Just above this lateral stripe is a broad, dusky, longitudinal band, and between this latter and the central dorsal stripe is a broad whitish band, often marked with fine whitish lines, but so delicate as not to interfere with the general color of the body. On the more central body segments are usually eight black spots, extending in an

irregular transverse line from one stigmatal stripe to the other. The breathing pores are black in color, the head brownish, and the entire ventral portion light.

The pupa.—When full grown the bollworm leaves its food plant, burrows below the soil surface some 2 to 5 inches, and constructs a more or less upright cell, reaching to near the surface of the ground to allow of the ready exit of the moth. At the bottom, the tube is somewhat more enlarged, and here the larva sheds its skin and enters the quiescent pupal stage. There is considerable variation in the method of pupation, depending on the character of the soil, and not infrequently this stage may be entered within the ear of corn or the cotton boll in which the larva was feeding. The pupal stage during summer lasts from nine to twelve days.

The adult.—The parent moth, like the larva, is extremely variable in general color, ranging in different individuals from a dull ochre-yellow to a dull olive-green. The wing expanse is about $1\frac{1}{2}$ inches, and the body is about seven-eighths of an inch in length. The males may be most readily distinguished from the females by the stouter abdomen of the latter. The accompanying illustration (fig. 2) shows the bollworm moth in a rather characteristic position, and will aid in its identification, where help is needed.

Life cycle.—From the above statements as to the length of the respective stages, it is seen that the insect may go through all of its transformations from egg to adult, during summer, in about twenty-three to thirty days. The average of six individuals reared during June and July, at Victoria, Tex., was twenty-eight days. During spring and fall the rate of development is much slower. The average time for the complete life cycle of nine individuals during the spring at Victoria was forty-four days.

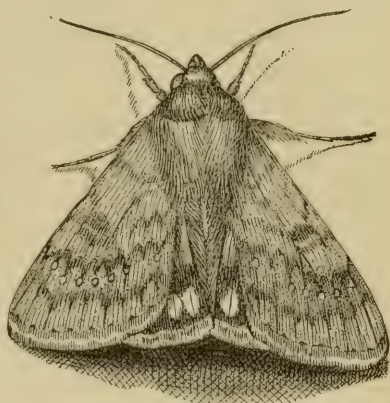


FIG. 2.—Bollworm moth in natural position, wings folded; about twice natural size (original).

FOOD PLANTS.

The bollworm is practically omnivorous, and the list of plants upon which it has been found feeding is very large. In the United States it is destructive principally to corn, cotton, tomatoes, and various garden crops. The combined annual loss from this species in this and foreign countries must be very great, and easily places the bollworm among the foremost injurious insects of the world.

NUMBER OF GENERATIONS.

The number of annual generations of the bollworm in the cotton belt varies from about four to seven, depending on the latitude, with an average of about five. Owing to the irregularity in time of appearance of moths from the ground in the spring and the variation in rate of growth of different individuals from various causes, there results a considerable breaking up of generations, so that these are rarely marked. Thus, in 1903, in Texas, the insect in all stages, from egg to adult, was to be found in considerable numbers in the same field at any given time throughout the season. This condition, however, may have been due in part to the lateness of the season. Furthermore, there may be numerous distinct generations in the same locality, or even on the same plantation, depending on the relative age of the different fields of corn. It is therefore evident that in considering the generations of the bollworm only the majority of the individuals may be referred to.

In general, the moths are out in maximum numbers in the spring in any locality in the cotton belt at a time when field corn is mostly from 8 to 20 inches high, and they deposit by far the greater part of their eggs on these plants. The first generation of bollworms feeds mostly on the tender central roll of leaves of the young corn, the moths from these larvæ appearing during late May or early June. These likewise oviposit largely on corn, which by this time may be commencing to tassel somewhat and to show young ears, the larvæ feeding on the buds, unfolding tassels, and forming ears, as the case may be. Moths from this, the second, generation of larvæ make their appearance from late June until early July and deposit eggs on corn, especially on the silks, which are now appearing quite generally. The third generation of bollworms infests the soft milky ears of corn during early July, and the moths appear again late in July or early in August. By this time, however, the corn throughout the country has begun to dry and the ears to harden and is no longer attractive to the moths for egg laying. They therefore fly to neighboring cotton, from which they secure nectar as food, and on which they deposit the greater part of their eggs. The more or less simultaneous hardening of corn during late July results in a general migration of the moths to the cotton fields, and injury to cotton during August from the fourth generation of bollworms may often be very extensive. Not infrequently, however, cotton may be severely ravaged by the fifth generation during late September or early October. Larvæ of the fifth generation attain full growth usually by the middle of October, burrow into the ground, and transform to pupæ, in which condition the majority remain during the winter, the moths appearing the fol-

lowing spring in time to oviposit on young corn. If, however, the autumn is warm, a small proportion of the pupæ may transform to moths, which oviposit again on cotton, and a few bollworms are thus to be found in cotton fields until the plants are destroyed by frost. It is supposed that a few of the late-appearing moths may hibernate as such during the winter, and hence appear early in the spring, thus adding to the confusion of generations, but the evidence on this point is far from satisfactory.

THE BOLLWORM ON CORN.

Corn is, without doubt, the preferred food of the bollworm, and material injury to cotton occurs only after the corn has become too old to furnish suitable food. A consideration of the bollworm on cotton, therefore, requires brief mention of its occurrence on corn.

The eggs are deposited quite promiscuously over the plant. On young corn the distribution of eggs is confined largely to the leaves, and as many as twenty to twenty-five may often be counted on a single small plant. On corn in tassel and fresh silk, eggs are deposited quite generally over these parts, and the number which may be deposited on a single plant is often surprisingly large.

Notwithstanding the large number of eggs which may be deposited on corn, only a small proportion of the larvæ from these ever reach full growth. Larvæ hatching from eggs laid on other parts of the plant than the silks will mostly perish in their search for suitable food; while, owing to their cannibalistic habits, from the numerous eggs deposited by the moths on the fresh silks, not more than two or three larvæ will succeed in attaining maturity in the same ear. Corn, in addition to being an excellent trap crop to attract moths away from cotton, also serves to reduce the insects in numbers.

Injury to young corn by the first generation is confined largely to the "bud," and becomes apparent as the more central, ragged, and shot-holed leaves unfold (fig. 3). It is rarely serious in extent. Injury by an allied species, the fall army worm (*Laphygma frugiperda* S. & A.) is often very severe on June corn planted in early summer, and has been erroneously attributed to the bollworm. Likewise, injury by the second generation of bollworms is comparatively insignificant, but the third generation, affecting roasting ears, may be the cause of much loss. Injury is not confined to the quantity of kernels of corn eaten, which in the aggregate must be considerable, but more important damage results from the molding and souring of the ear, favored by the filthy excrement and exuded milky juices from the injured grain (fig. 4). No practical means, aside from late fall or winter plowing, have, as yet, been discovered for reducing bollworm injury to corn.

THE BOLLWORM ON COTTON.

Noticeable injury to cotton usually begins with the August generation of larvæ. A few bollworms may have been found in cotton



FIG. 3.—Young corn plant showing injury to "bud" by bollworm—natural size (original).

earlier in the season, but the amount of injury done by these is of comparatively little importance.

Eggs are deposited more or less generally over all parts of the plant. The bollworm on hatching will usually at once devour the eggshell from which it has just escaped. If the place of its birth be on a bud, square, or flower, it may soon penetrate within. If on a leaf, stem, or petiole, it soon begins to crawl up and down, here and there, over the plant, searching for the tender buds or squares. In the course of this more or less aimless wandering from one leaf or part to another, it feeds freely enough to insure its death if poison be present on the plants. The average distribution of eggs over the cotton plants, therefore, has an important bearing on the subject of bollworm control by the use of poisons.

During August, 1903, moths were watched late in the evening while they were ovipositing on cotton, and an accurate record was made

of the number and distribution of the eggs placed on the plants. The combined record of the eight moths observed is as follows:

Distribution of bollworm eggs on cotton plants.

Eggs deposited on—

Leaves, upper surface.....	40
Leaves, lower surface.....	44
Squares.....	35
Flowers.....	11
Leaf stalks (petioles).....	11
Stems.....	15
Bolls.....	5
Weeds in cotton field.....	27
Total number of plants deposited on.....	63



FIG. 4.—Roasting ear infested by bollworm—natural size (original).

This shows that out of a total of 161 eggs placed on the different parts of the cotton plants, 84, or 52 per cent, were deposited on the leaves. The eggs placed on leaves, leaf stalks, stems, and weeds may be considered in practically the same class with respect to the susceptibility of the resulting larvæ to poisons, and the percentage is thus raised from 52 to approximately 73.

The combined result of the examination of eight cotton plants for bollworm eggs, taken at random in a typical field, is as follows:

Distribution of bollworm eggs on plants.

Eggs found on—

Leaves	23
Squares	15
Flowers	0
Leaf stalks (petioles)	2

By this method it is shown that approximately 65 per cent of the eggs found on the plants was on other parts than the squares, flowers, and bolls.



FIG. 5.—Normal cotton square at left; flared square at right, due to bollworm attack—natural size (original).

Bollworm injury to cotton squares is quite characteristic and is not likely to be confused with that of any other insect, except, possibly, with that of *Thecla pæas*. The injury done by this latter species is, however, comparatively insignificant. The usual effect of bollworm injury on the squares is to cause them to “flare” and to drop (fig. 5). But there are other causes which bring about this “flaring” and drop-

ping of the squares, as injury by the boll weevil and the punctures of the sharpshooter and other sucking insects. Under certain climatic conditions, as extremes in rainfall and drought, the plant may of itself throw off a considerable number of squares and young bolls. Much of this shedding, whatever the cause, is attributed by planters to the bollworm, and the insect is thus frequently charged with damage greatly out of proportion to the real injury inflicted.

Injury to the boll is likewise easily recognized (figs. 6 and 7). A circular hole is eaten into the boll, usually near its base, of sufficient size

to admit the body of the larva. The worm may simply penetrate the boll, leaving it for another, or it may eat quite to the interior and devour more or less of the contents. An individual bollworm may traverse a plant many times in its search for food, or even leave the plant. The traveling may be done during any part of the day, though it is to be noted that the hot sun is avoided as much as possible. The amount of damage done by a single larva is quite variable and hard to determine. The worm may find a suitable

boll and largely devour it, or a considerable number may be eaten into, one being left for another on account of its hardness or for other reasons. When feeding on squares, a large number of these must necessarily be devoured, by reason of their small size, to furnish the food required for the larva in its growth.

The moths or parents of the bollworm are largely nocturnal in their habits, beginning to feed, and the females to oviposit, about twilight, yet it is to be noted that in times of abundance, as during August, many moths may be seen feeding and ovipositing during almost any part of the day, but especially in the afternoon if the sun be more or



FIG. 6.—Cotton boll, showing mode of attack by bollworm from within—natural size (original).

less clouded. The principal food of the moths in cotton fields is the nectar secreted by the glands at the base of the bracts surrounding the squares and flowers. Many moths are doubtless attracted to cotton fields on account of the abundance of nectar, and we have the unusual condition in Nature of a plant attracting its own worst enemy.

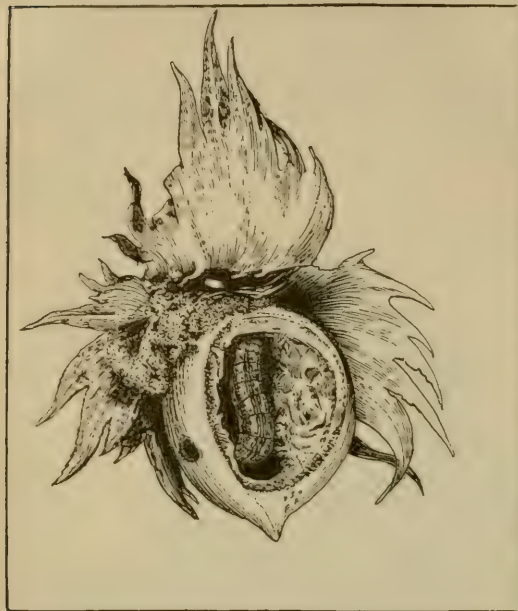


FIG. 7.—Opened boll to show bollworm at work within—natural size (original).

It is difficult to determine the number of eggs deposited by a moth under normal conditions in the field. In the laboratory at Victoria moths kept in confinement and fed on sugar water averaged about 1,200 eggs each, with a range of from 900 to about 2,200. This is a considerably larger number than has heretofore been accredited to this species. Estimating that only 10 per cent of the 1,200 eggs hatch, and that of this number one-half will produce females capable of laying eggs,

the progeny of one moth appearing in spring by the fourth, or August, generation would be 25,920 bollworms, and by September, or the fifth generation, the number would be 155,520. It is thus readily understood how, under favorable conditions, the bollworm may become so numerous and destructive.

SOME FACTORS WHICH TEND TO KEEP BOLLWORMS REDUCED.

Owing to their habits of feeding more or less protected from the attack of parasitic and predaceous insects, bollworms enjoy considerable freedom from important natural checks. The eggs are freely parasitized by a small hymenopterous insect, during certain periods from 50 to 75 per cent being thus destroyed. The larvæ are preyed upon by several species of wasps, and also by ants, which do considerable good in this way. They are parasitized by certain Tachina flies, and succumb in considerable numbers at times to a bacterial disease. During the spring and fall, when the variation in temperature is greater, many bollworms die of this disease before entering the soil to pupate, or shortly afterwards.

Under this heading may also be mentioned the cannibalistic habits of the bollworms themselves. Of the many small larvæ which may be found in a recently silked ear of corn, rarely more than two or three will escape being devoured by their larger fellows, and succeed in reaching maturity. Weather conditions also exert an important influence on this species. In general, rains late in July and early in August favor bollworm injury. Bollworms, along with insects in general, are food for many species of birds and for barnyard fowls. At Calvert, Tex., the present year a flock of turkeys was observed feeding on bollworms infesting alfalfa. The distended crops of the turkeys of the entire flock gave evidence of the considerable number of larvæ which they had eaten during the morning.

INEFFECTIVE METHODS OF BOLLWORM CONTROL.

During periods of serious bollworm injury various methods are often resorted to by planters in their efforts to prevent the destruction of the crop. Some of these do little, if any, good and, as a rule, result only in a waste of time and money. Attention is called to the more common of these, in order that this needless loss may not occur in the future.

LIGHTS FOR TRAPPING MOTHS.

Various light traps have often been advised, and reports are not wanting as to their efficiency. Nevertheless the careful investigation of this subject by this Division has shown that the use of lights for attracting and destroying bollworm moths is without beneficial results. It is true that bollworm moths have been captured at lights, but these have been few in number and mostly males or worn-out females. Numerous species of moths and other insects may be caught, often in large quantities, by lights placed in cotton fields. A careful examination of the catch, however, will show comparatively few bollworm moths. The other insects caught include many that are beneficial by preying upon injurious species. There can be no doubt that money expended in the use of light traps is entirely lost.

POISONED SWEETS.

The use of poisoned baits, as vinegar and molasses poisoned with cobalt to attract the moths in feeding, has been more or less recommended for many years. The practice has been to pour out the bait on plates, placing them on small stakes set up here and there in the cotton field. Experiments the past year with poisoned baits have given no results of material value in bollworm control, though in times of scarcity of food the moths might be attracted in greater numbers. On the whole the method has nothing to recommend it.

BURNING SULPHUR IN COTTON FIELDS.

This appears to be a comparatively recent practice. Burning sulphur is hauled through the cotton fields between the rows on small sleds. Considerable sulphur was used in this way during August of the past year. Its advocates claim that the fumes of the sulphur drive the bollworm moths out of the field. The experiments of the writer with burning sulphur in cotton fields, in 1903, do not indicate any possible benefit from its use. Bollworm and cotton caterpillar moths are often frightened from the plants, but usually fly only a short distance before darting among the plants again. The simple walking between the rows would disturb the millers almost as much, and the recommendation has no valid foundation.

RESISTANT VARIETIES.

The idea of making a crop of cotton ahead of the bollworm by the early planting of early varieties has, to a limited extent, been confused with the idea of immunity on the part of the varieties recommended. It should be stated that, so far as known, there are no varieties of cotton immune to attack by the bollworm. It will be remembered that, in regard to its feeding habits, this insect is practically omnivorous, and it is not likely that it would be deterred by the slight differences occurring in the different varieties of cotton.

FIELD EXPERIMENTS IN 1903.

The field experiments of the Division of Entomology with the bollworm during the past season were conducted along the following lines:

- (1) To determine the possibility of making a crop of cotton before the period of greatest bollworm injury by the early planting of an early-maturing variety of cotton, aided by thorough cultivation.
- (2) To determine the value in bollworm control of spraying or dusting cotton with arsenical poisons.
- (3) To determine the value of corn as a trap crop in protecting cotton from bollworm injury.

Incidentally, tests were made of light traps, poisoned sweets, fumigation of fields with sulphur, and methods of similar character.

CULTURAL METHODS.

The more or less general rains which prevailed in Texas during the winter and early spring of 1902-3 delayed the planting season, which was everywhere from about four to six weeks late, and in this important respect conditions were unfavorable for the experiments involving the early planting of cotton.

The accompanying diagram shows the arrangement, treatment of, and yield from the respective plats in the experiment acreage located on the plantation of Capt. B. D. Wilson, at Hetty, Tex. The plats

were located on fairly uniform rich "second-bottom" soil, capable of producing during favorable seasons about 1 bale of cotton to the acre. Bollworms had been especially destructive to the cotton grown on this land the year previous. According to Captain Wilson, their injury on the plantation during 1902 was such that from 850 acres planted in cotton only 28 bales were gathered.

Experimental cotton plats of the Department of Agriculture at Helty, Tex., 1903.

Plat 1. 5 acres. King seed. Planted May 1. Thorough cultivation. Yield, 6,741 pounds seed cotton, or 1,348.20 pounds per acre.	Turn row.	Plat 5. 5 acres. Gin seed. Planted May 1. Replanted May 20. Thorough cultivation. Yield, 938 pounds seed cotton, or 187.60 pounds per acre.
Plat 2. 5 acres. King seed. Planted May 1. Average cultivation. Yield, 5,020 pounds seed cotton, or 1,004 pounds per acre.		Plat 6. 5 acres. Gin seed. Planted May 1. Replanted May 20. Average cultivation. Yield, 887 pounds seed cotton, or 177.40 pounds per acre.
Plat 3. 5 acres. King seed. Planted June 1-2. Thorough cultivation. Yield, 1,804 pounds seed cotton, or 360.80 pounds per acre.		Plat 7. 5 acres. Gin seed. Planted June 1-2. Thorough cultivation. Yield, 692 pounds seed cotton, or 138.40 pounds per acre.
Plat 4. 5 acres. King seed. Planted June 1-2. Average cultivation. Yield, 1,379 pounds seed cotton, or 275.80 pounds per acre.		Plat 8. 5 acres. Gin seed. Planted June 1-2. Average cultivation. Yield, 647 pounds seed cotton, or 129.40 pounds per acre.

It will be noted that the scheme includes the comparison of an early-maturing variety of cotton (King) with cotton grown from common

gin seed; of early and late planting; and of thorough with average cultivation under both of the above conditions. By thorough cultivation is meant five to six plowings with three or four choppings, and by average cultivation, three to four plowings with two or three choppings. The rows were 5 feet apart and the plants were chopped to 30 inches in the row.

It was desired to determine by comparison the relation of these several methods of treatment to the production of cotton during a season of severe bollworm injury. Fortunately, from an experimental standpoint, this insect was quite numerous and destructive in these plats, and on the plantation generally, during August and the first half of September, and the results obtained, therefore, bear directly on the question of the possibility of reducing bollworm injury by cultural methods.

The considerable difference in yield to be noted between the King plats and the plats planted to common gin seed must, in fairness, be attributed in part to the abnormal lateness of the season. While a full growing and fruiting season was afforded the early-maturing variety, the later common gin seed cotton was cut off by frost. The latter, with an average season, would no doubt have matured a considerably larger crop.

In the comparisons between plats 1 and 5 and between plats 2 and 6 it should be noted that plats 5 and 6 were entirely replanted twenty days later than date of first planting, so that these plats were in fact planted rather late instead of early. But the necessity for replanting was due entirely to the inferiority of the common gin seed to the King seed. The superior vitality of the King seed resulted in a satisfactory stand under the adverse weather conditions then prevailing, whereas the gin seed germinated very poorly. The results are in full accord with the observations made on the respective plats throughout the season. Plats 1 and 2 suffered much less from bollworms during August and September by reason of their more matured condition than did the other plats. The injury was most marked on the late fruiting and comparatively unprolific plants from native gin seed, and a considerable part of the reduction in yield must be attributed to this fact.

For ready comparison the more important results of the experiments at Hetty are shown in the following statements:

Early-maturing variety versus native gin seed.

Yield per acre with early-planted King seed and thorough cultivation,	
pounds seed cotton	1, 348. 20
Yield per acre with early-planted native gin seed and thorough cultivation,	
pounds seed cotton	187. 60
Yield per acre in favor of King seed	pounds seed cotton.. 1, 160. 60
Value of excess per acre, at 3 cents per pound of seed cotton	\$34. 81

Early-planted King seed, with thorough cultivation versus late-planted native gin seed with average cultivation.

Yield per acre with early-planted King seed and thorough cultivation, pounds seed cotton	1,348.20
Yield per acre with late-planted native gin seed and average cultivation, pounds seed cotton	129.40
Yield per acre in favor of early-planted King seed with thorough cultivation	pounds seed cotton.. 1,218.80
Value of excess per acre, at 3 cents per pound of seed cotton	\$36.56

Early planting with thorough cultivation versus late planting with thorough cultivation.

Yield per acre with early-planted King seed and thorough cultivation, pounds seed cotton	1,348.20
Yield per acre with late-planted King seed and thorough cultivation, pounds seed cotton	360.80
Yield per acre in favor of early planting	pounds seed cotton.. 987.40
Value per acre in favor of early planting, at 3 cents per pound of seed cotton	\$29.62

Thorough cultivation versus average cultivation.

Yield per acre with early-planted King seed and thorough cultivation, pounds seed cotton	1,348.20
Yield per acre with early-planted King seed and average cultivation, pounds seed cotton	1,004.00
Yield per acre in favor of thorough cultivation ..	pounds seed cotton.. 344.20
Value of excess per acre, at 3 cents per pound of seed cotton	\$10.32

Early planting with thorough cultivation versus late planting with average cultivation.

Yield per acre with early-planted King seed and thorough cultivation, pounds seed cotton	1,348.20
Yield per acre with late-planted King seed and average cultivation, pounds seed cotton	275.80
Yield per acre in favor early planting and thorough cultivation, pounds seed cotton	1,072.40
Value of excess, at 3 cents per pound of seed cotton	\$32.17

ARSENICAL POISONS.

Although poisons have long been recommended for bollworm control on cotton, their use has not been adopted to any extent. This may have been due to the fact that their value in this particular had not been demonstrated in any such way as to furnish tangible results. The possible usefulness of poisons is based on facts connected with the early life of the bollworm, not ordinarily taken into consideration by planters. Bollworms are not usually noticed until they have begun to bore into the squares, flowers, and bolls, and the application of poisons at this time manifestly appears to be of little use.

It has already been shown (page 14) that from 65 to 73 per cent of the eggs deposited by bollworm moths on the cotton plant, are so

placed that the resulting larvæ would be more or less subject to poisoning, if poisons were present on the plants. As bearing on this point the following experiments are of interest:

During June, a cotton plant bearing numerous squares, flowers, and bolls, was sprayed with Paris green at the rate of 1 pound to 100 gallons of water. A few hours later 100 larvæ, just hatched, were distributed over the plant, which was then covered with a large wire-screen cage for protection. Subsequent examinations did not reveal any bollworms whatever on the plant, the larvæ doubtless being all destroyed by the poison.

A similar test was made during August, but only 50 young larvæ were used. Out of this number but one bollworm survived, which was found when about two weeks old feeding on a half-grown boll.

Field experiments with poison were conducted at Hetty and at Calvert, Tex., and, although started somewhat late, nevertheless gave decidedly favorable results.

At Hetty, a 10-acre cut of uniform, late, native cotton, growing on bottom land, was selected, 5 acres of which was poisoned and 5 acres was left unpoisoned, as a basis for comparison. Paris green was dusted freely over the plants by the usual dusting method, namely, from bags on the ends of a short pole carried by a man on horseback. Applications were made August 22 and 31 and September 8, using approximately 3 pounds of the "green" per acre at each dusting. The results are indicated in the following table:

Comparison of yields from plat dusted with Paris green and plat left untreated.

Yield from poisoned 5-acre plat.....	pounds seed cotton..	2,720
Yield from unpoisoned 5-acre plat.....	do.....	1,434
Yield in favor of poisoning.....	do.....	1,286
Value of excess, at 3 cents per pound of seed cotton.....		\$38.58
Cost of 45 pounds of Paris green, at 18 cents per pound		\$8.10
Cost of labor, one man three mornings, at 50 cents per morning		1.50
Total cost of poisoning.....		9.60
Net gain per acre in favor of poisoning.....		5.79

At Calvert poisons were applied by the dusting method and also by means of a spray pump. The spraying was done with a barrel sprayer furnished with two leads of hose and four nozzles. A team, wagon, and two men were required, one man to drive and pump, the other to handle the nozzles at the rear end of the wagon. "Green arsenoid" was used, at the rate of 1 pound to 50 gallons of water, which would poison approximately 1 acre. With water one-half mile distant, only 5 to 6 acres per day could be sprayed. With a more convenient water supply and with geared spraying machinery, the ground covered per

day, could, no doubt, be considerably increased. Below is the treatment given and the results from the respective plats:

Comparison of yields from plat sprayed with "green arsenoid," plat dusted with Paris green, and plat left untreated.

Plat I, 3.89 acres, left untreated for comparison; yield of seed cotton per acre	pounds..	246.0
Plat II, 4.37 acres, treated with "green arsenoid," 1 pound to 50 gallons water; sprayed August 14, 28, and September 5; yield of seed cotton per acre, pounds		554.8
Increased yield of seed cotton per acre in favor of spraying ..	pounds ..	308.8
Value of gain per acre, at 3 cents per pound of seed cotton		\$9.26
Cost of three sprayings per acre, including labor and poisons		2.27
Net gain per acre in favor of spraying		6.99
Plat III, 4.38 acres, dusted with Paris green, average of 3 pounds per acre; poisoned August 15, 22, and September 4; yield of seed cotton per acre, pounds		460.21
Increased yield of seed cotton per acre from poisoning	pounds..	214.21
Value of increase per acre, at 3 cents per pound of seed cotton		\$6.42
Cost of three dustings per acre, including labor and poisons		1.98
Net gain per acre from poisoning		4.44

CORN AS A TRAP CROP.

Attention has already been called to the fact that corn, when in a suitable condition, is the preferred food of the bollworm, and that cotton is not materially injured until after the corn has begun to harden. It would therefore appear that bollworms might be largely kept out of cotton by the proper use of corn as a trap crop. The use of corn in this way has been frequently recommended by this Division, and instances are not wanting where good results have been secured. Nevertheless, for reasons not apparent, this expedient has been but little adopted.

Extensive tests of corn as a trap crop in protecting cotton from bollworm injury were made the past year, both at Calvert and at Willspoint, Tex. Unfavorable weather and soil conditions, however, necessitated considerable change in the original plans, and it was possible to have corn in silk for the August generation only. But it is usually this generation that causes the greatest injury to cotton, and the control of which is especially important. It is not permitted, as in the experiments previously reported, to indicate the value of the trap crop in pounds of seed cotton, as it is manifestly impossible to arrange a control plat which would meet the necessary condition of adjacent location to the plat under test, and at the same time be entirely free from the protective influence of the corn. Bollworm moths fly about freely in the cotton fields and would be attracted a considerable

distance by the trap crop. Its value, in fact, depends to a considerable extent on this migratory habit of the moths.

The experiments in question, as finally arranged, provided for belts of corn around and through the cotton fields, planted so as to be in prime silking condition about August 1. By this means, the large generation of moths appearing in late July and August, from larvæ infesting roasting ears in the surrounding cornfields, was largely detracted from the cotton, and egg-laying was concentrated on the trap rows of corn. The number of eggs found on a single corn plant was often surprisingly great. Thus, in the trap rows at Willspoint during early August, when the moths were out in large numbers, 804 bollworm eggs were counted on a single corn plant, and the average of eight typical plants at this time was 495 per plant, distributed as follows: 175 on the leaves, 45 on the leaf sheaths, 120 on the tassels, and 155 on the silks. Furthermore, the trap rows of corn were attractive to the moths all through the season, from the time the plants were from 12 to 18 inches high until ripening began. The total number of eggs deposited on a plant during its entire period of growth must be very great, and a simple calculation will indicate the enormous number of bollworm eggs that are kept from cotton by a series of belts of corn planted through the cotton field.

It might be supposed that, by thus furnishing the insect with its favorite food, its increase and consequent greater destructiveness would be the result. This, however, is not the case. From the several hundred eggs that may be found on a single corn plant but two or three larvæ will eventually succeed in attaining their growth, owing to the cannibalistic habits of the larvæ themselves, and for other reasons already pointed out.

SPECIFIC RECOMMENDATIONS.

The earlier investigations of the Division of Entomology and its work the past season warrant the recommendation of the following methods of lessening bollworm injury:

I. Plant an early maturing variety of cotton as early as possible in the spring and give the plants good cultivation. By good cultivation is meant five or six plowings, with three or four choppings. By plowing and cultivating in this way a good crop may usually be insured before the bollworms become destructive in August. In the territory infested with the cotton boll weevil this course becomes doubly necessary, as it is only by such methods that ordinarily a crop of cotton may be made. The possibility of the plants developing a crop after the bollworms may leave is removed on account of the presence of the weevil. Early planting of early maturing varieties will also allow of the crop being gathered much earlier in the fall than is possible with plantings of ordinary gin seed at the usual time. It will thus become possible to a considerable

extent to clear the land of the plants and plow in the fall, which, aside from being good farm practice, will exert a very beneficial influence in controlling the bollworm by breaking open their hibernation cells and exposing the pupæ to the influences of cold and rain during the winter.

The above recommendations involve no outlay of labor and capital not requisite to successful cotton culture, and, furthermore, agree entirely with the best known methods of circumventing the ravages of the Mexican cotton boll weevil. It thus becomes possible to secure the maximum amount of freedom from the depredations of the boll weevil and the bollworm by one and the same course of farm practice.

II. The use of corn as a trap crop may be advantageously combined with the cultural methods indicated above, especially so if it is not found possible to plant early on account of climatic conditions or for other reasons. In planting cotton leave vacant strips across the field every 200 or 300 feet, sufficiently wide for planting 10 or 12 rows of corn. These strips should be planted with corn so that it will be in prime silking condition not later than August 1. Under favorable conditions of rainfall and with good cultivation, Mexican June corn planted by June 1 will be tasseling and silking freely by August 1. Plant cowpeas in the corn belts, so that the plants will be flowering along with the appearance of the tassels and silks on the corn. The cowpeas are to furnish food for the moths and will largely prevent their going to the cotton for food and depositing thereon a certain proportion of their eggs. The corn may be allowed to mature and may be harvested in the usual way. Sufficient corn may be grown in these belts to meet a portion of the needs of the plantation and at the same time afford material protection to the cotton crop from bollworms. As will at once appear, *the planting of corn through the cotton field at the usual time in the spring is bad practice from a bollworm point of view.* With the hardening of the corn during July the insects turn their attention to cotton. The trap rows of corn should not be tasseling and silking before about August 1.

III. Experiments with poisons the past year indicate that these may be profitably used in lessening bollworm injury to cotton. The poisons should be applied to the plants in time to insure the destruction of the maximum number of young larvæ of the August generation. In general, this will be about August 1. When it is noticed that the moths are becoming abundant in the cotton fields the first application should be made, and a second application should follow a week or ten days later. The occurrence of even a moderate rain shortly after the poison has been applied will necessitate another application if best results are to be secured. If conditions are favorable for bollworm injury poison should be used again about September 1 in time to check injury from the September generation of larvæ. In the work of poisoning special pains should be taken to cover all parts

of the plant as nearly as possible. The poisons should be distributed much more generally over the plant than is necessary for the cotton caterpillar.

Of the modes of applying the poison little need be said. The general use of poisons against the cotton caterpillar has familiarized most planters with the details of this work. In point of convenience the dusting method is to be recommended. If an abundance of water is at hand, suitable spraying machinery may be used. The amount of poison used in the dusting method will be greater than that required to poison an equal area by spraying, but in dusting there will be a saving in labor and machinery, and what is more important, the work may be done more rapidly. The question of how to apply the poisons most economically, and in a way to secure the best results, should be settled by each planter according to his conditions. If the work be done with spraying machinery, a poison, such as Paris green, should be used at the rate of 1 pound to every 50 gallons of water, and if the dusting method is adopted, from 2 to 3 pounds will be required per acre for each application.

In conclusion, attention should be called to the entire practicability of the methods recommended. They may be used singly, or any two may be employed, as the early planting of early varieties, supplemented by the use of poisons or trap crops; or all three may be employed in conjunction, and, if properly managed, should give a large degree of freedom from bollworm injury.

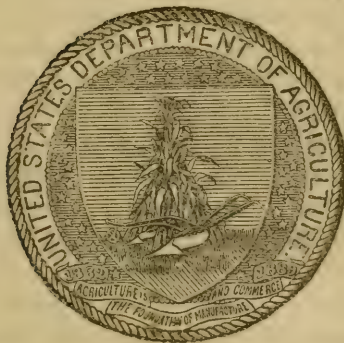
U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 196.

USEFULNESS OF THE AMERICAN TOAD.

BY

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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,

DIVISION OF ENTOMOLOGY,

Washington, D. C., April 22, 1904.

DEAR SIR: I submit herewith a short paper on The Usefulness of the American Toad, prepared by A. H. Kirkland, M. S., of Boston, Mass., an entomologist and writer on entomological subjects. Mr. Kirkland has made a somewhat thorough and extended study of the toad as a destroyer of insects, arriving at the conclusion that this little animal is a valuable friend to all who are engaged in agriculture, and supporting this conclusion with evidence derived from his investigations. In the hope that the toad's life history and habits may be better understood, its usefulness more fully appreciated, and its protection from wanton destruction secured, it is recommended that this paper be published as a Farmers' Bulletin.

Respectfully,

L. O. HOWARD,

Entomologist.

Hon. JAMES WILSON,

Secretary of Agriculture.

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USEFULNESS OF THE AMERICAN TOAD.

INTRODUCTION.

The heavy tax levied by insects on nearly all agricultural crops is well known to farmers. Nearly as well known, thanks to Experiment Station experts and others, are the principal remedies for combating these pests. But in the long run nature provides the most efficient checks on insect increase and these often are but little understood or appreciated. While the value of birds as destroyers of noxious insects is now becoming generally recognized, the silent, inconspicuous work of insect parasites and certain predaceous animals receives but slight recognition even from those who are most directly benefited. Thus the common toad,^a nocturnal, of quiet habit and appearance, renders notable service to farmers and gardeners throughout the entire growing season; yet to many its worth is unknown, while to others it is even an object of disgust, if not of fear. It must be admitted that to some the toad can never be an attractive animal. Nature has denied it the gay colors of bird life or even the sinuous beauty of some of its reptilian relatives. Yet, judged by the standard of good works, the toad does not suffer by comparison with any of the lower animals.

The toad has always borne the burden of false and even ludicrous misrepresentations. We have adopted in their entirety the principal European traditions concerning the toad as set forth by the early writers on natural history. These ancient savants, who did so much to establish the study of nature, had the failing, not confined to that age, of confounding fancy with fact. Thus the popular superstitions of that time are curiously interwoven with their statements concerning the life history and habits of the toad. The early writings on this subject teem with vague and ludicrous fancies of the toad's venomous qualities, its medicinal virtues, and more commonly of the valuable toadstone or jewel to be found in its head. All these traditions are to be met with even in this era of progress, and coupled with them we hear of the equally surprising ability of the toad to produce

^a The information given in this bulletin relates chiefly to our common eastern toad (*Bufo lentiginosus americanus* Le C.). Other species have similar habits where the same classes of insects are available for food.—EDITOR.

warts on the hands; to poison infants by its breath; to bring good fortune to the house in whose new-made cellar it takes up its abode; and, finally, to cause bloody milk in cows if killed by accident or design. The writer well recalls the shock his credulity received when in the inquisitive stage of boyhood he faithfully tested several of these superstitions with only negative results. When so much that is false has been written about the toad it may not be amiss to increase the scanty literature of facts concerning this humble servant of man as determined by a somewhat intimate acquaintance extending over a decade or more.

LIFE HISTORY AND HABITS.

To the nature lover there are few more interesting subjects than the development and habits of the toad. In New England toads do not bestir themselves until April or May, but in more southern latitudes March finds them wakening from their winter's sleep and beginning their annual migration toward the breeding ponds, where a little later is heard the soft, drowsy, musical trilling of the males, so well described by Gibson as the "sweetest sound in nature." The number of toads which migrate even to a small pond is remarkable. The writer once counted 356 toads on the shores of a pond containing scarcely half an acre. Mating is commenced as soon as the water is reached, or even before. The tiny black eggs, with their gelatinous covering, are laid in long "ropes," the envelope swelling to a notable degree as soon as it comes in contact with the water, thus forming a mass many times larger than the body of the parent toad. In two weeks, or even sooner if the water be warm, the eggs hatch and the young tadpoles feed greedily upon the gelatinous envelope. Next the slimy deposits common to ponds are attacked. The tadpoles grow rapidly, until by June or July the legs develop, the tail is absorbed, and the young toads leave the pond which has sheltered them, never to return except for brief visits at the mating season.

The little toads are very sensitive to heat and secrete themselves under leaves, rubbish, stones, etc., during the day; but let a vigorous shower descend and frequently walks, roads, and gardens at once become peopled with these thirsty leaping creatures. So sudden is their appearance under these conditions as to lead to the popular belief that they rain down. The inability of toads to endure heat serves as an indirect protection for them at this stage. They are delectable morsels to many birds, and, were it not for the fact that they are obliged to seek shelter by day, large numbers would be destroyed. As it is, many are devoured by the predaceous birds and mammals which prowl at night.

It seems probable that the toad does not begin to reproduce until the fourth year. The number of eggs laid by a full-grown female

toad is remarkable. It is a rule of nature that where the chance for a species reaching maturity is small the fecundity is large, and this rule is well illustrated in the case of the animal under discussion. The writer once removed 1,279 eggs from a female toad which had already commenced laying. The total egg production is better indicated by the record of 7,587 and 11,545 eggs obtained from two toads by Dr. C. F. Hodge, Clark University, Worcester, Mass., as recorded in his book entitled "Nature Study and Life."

Many stories are extant concerning the longevity of the toad. These animals are said to have been found embedded in rocks, trees, masonry, etc., thus indicating that it was possible for them to exist in dormant condition for many years. The writer has gone to some trouble to investigate statements of this kind coming to his attention without finding a single case where there was conclusive evidence of such a prolonged dormant state. On the other hand, we have the experiment of M. Herrisant, who in 1777 embedded three toads in plaster and placed them in the archives of the French Academy of Sciences. At the end of eighteen months two of the toads were still alive. In 1817 Doctor Edwards repeated this experiment, but submerged the plaster blocks in water, with the result that all of the toads died. Buckland buried toads in cavities in sandstone and limestone and found that all the toads in sandstone were dead in thirteen months, while those in limestone survived for nearly two years.

The toad has a strong "homing" instinct, and lives year after year in the same locality. Convincing evidence has been furnished the writer of two toads that have occupied dooryards in two different towns for twelve and twenty-three years, respectively, while Mr. F. H. Mosher, Westport, Mass., has positive knowledge of a toad which occupied a certain feeding ground for at least eight years. In view of these facts, there can be little doubt that the toad attains to a considerable age.

The belief that the toad is venomous probably arises from its habit, when disturbed or roughly handled, of ejecting through the skin a certain milky acrid fluid. No harm attends contact with the fluid on the hands, but dogs attempting to bite toads show signs of discomfort, and even distress, due to this acrid skin secretion. That the fluid is not objectionable to all animals is shown by the avidity with which certain hawks and owls capture and eat toads.

It is not uncommon to find during the summer certain toads of much brighter colors than their fellows. This is due to the casting or molting of the skin, which takes place several times annually. Previous to molting, the toad seeks shelter and remains quiet for some time. The skin then splits, peels off, or is removed by aid of the forelegs, and is often eaten by the toad, which soon goes forth clad in fresher colors.

Though living alone through the summer, it is not an uncommon thing to find a dozen or more toads hibernating in a colony under some convenient rock or board. Winter quarters are sought quite early in the fall beneath rocks, leaves, or rubbish, or in other places where the action of the frost will not be severely felt. Figuier states that these animals freeze without being killed, and it is not unusual to find toads in winter apparently frozen stiff some distance below the surface of the soil.

FEEDING HABITS.

Soon after sundown, or even before on cool evenings, the toad emerges from its shelter and sallies forth in search of food. In country districts it nightly patrols over roadsides, gardens, cultivated and new-mown fields—in short, all places where insect life abounds and long grass or herbage does not obstruct its travel. In cities and villages the spots beneath electric lights are particularly favored, while lawns and walks also receive attention. The toad has learned that electric and other lights attract large numbers of flying insects, many of which fall injured to the ground below. At Amherst, Mass., the writer once observed eight well-fed toads holding festival beneath an arc light. During the flying season of the brown-tail moth in Massachusetts there is no more common night scene than that of the toads devouring the white moths which fall fluttering from the lamps above.

For two successive summers the writer had opportunity to make numerous observations on toads feeding under natural conditions at all hours of the night. From these observations and from stomach examinations it was apparent that the toad feeds continuously throughout the night, except when its food supply is unusually abundant, when periods of feeding and resting alternate. From such observations, as well as by studying toads confined in cages, it was found that in twenty-four hours the toad consumed a quantity of insect food equal to about four times its stomach capacity. In other words, the toad's stomach is practically filled and emptied four times in each twenty-four hours.

Dead or motionless food has little attraction for the toad. Only living and moving insects, centipedes, etc., are devoured. Cutworms, for example, are safe while they remain curled up, but let them commence crawling and they are soon snapped up by the toad. At first thought it strikes one as odd that the toad's tongue is attached in front and free behind, particularly as the tongue is its only means for capturing food. However, one needs only to watch the feeding of a toad for a few minutes to satisfy himself that this organ is well adapted to its work. The tongue is coated with a glutinous secretion and adheres firmly to the food it seizes. When the writer first took up the study

of the toad he confined a large specimen in a well-shaded box out of doors. So ravenous was its appetite that to provide sufficient insect food was quite a task until a satisfactory expedient suggested itself. When a hard bread crust was soaked in molasses and placed in the cage it attracted a sufficient number of flies, bees, ants, beetles, etc., to keep the toad well supplied with food. The toad would sit motionless beside the bread crust until a moving insect came within range, when its tongue would be thrown out with lightning-like rapidity and the insect, often on the wing, would suddenly disappear within the toad. The diet of this toad was varied with occasional fish worms, which, being too large to swallow at once, were forced down the gullet by means of the fore limbs.

THE FOOD OF THE TOAD.

As pointed out previously, the toad is of direct service to man by reason of the noxious insects which it destroys. Should it feed on beneficial insects, it would be to that extent an injurious animal. There is only one way to determine accurately to what extent an insectivorous animal is beneficial or injurious, and that is by a careful examination of the contents of a sufficiently large number of stomachs collected at different dates and over a suitable range of territory. While field observations furnish important circumstantial evidence and aid to an understanding of the kind and condition of food found, the stomach examinations, as Prof. F. E. L. Beal has so aptly put it, "constitute the court of final appeal." Patience, strategy, and good eyesight will enable one to study the feeding habits of such animals, but the absolute identification of the kind and quantity of their food can not be made at long range. For accurate results the material devoured must be available for careful analysis, often under a microscope.

The writer a few years ago collected and examined 149 toads' stomachs, particular effort being made to secure representatives from different sections and from a wide range of places, i. e., gardens, fields, hills, woodlands, city streets, etc., during every month of the feeding season. This number is doubtless too small to show the exact status of the toad in the region covered, yet it is sufficient to afford interesting data for some general conclusions. With the exception of a few stomachs preserved in formalin, all were examined while fresh, the stomachs being split along the outer curvature and the contents carefully washed into a glass dish. The material thus obtained was separated into its proper groups, identified, and its percentage of the entire bulk estimated and noted. The number of stomachs examined, by months, was as follows: April, 7; May, 30; June, 66; July, 29; August, 10; September, 7; total, 149.

Stomach contents of 149 toads, with percentage, by bulk, of each food element.

Food elements.	Part, by bulk.	Food elements.	Part, by bulk.
	<i>Per cent.</i>		<i>Per cent.</i>
Ants.....	19	Spiders.....	2
Cutworms.....	16	Sow-bugs.....	2
Thousand-legged worms.....	10	Potato beetles and allies.....	1
Tent caterpillars.....	9	Carion beetles.....	1
Ground beetles and allies.....	8	Miscellaneous beetles.....	1
May beetles and allies.....	6	Snails.....	1
Wireworm beetles and allies.....	5	Angleworms.....	1
Weevils.....	5	Vegetable detritus.....	1
Miscellaneous caterpillars.....	3	Gravel.....	1
Grasshoppers, crickets.....	3	Unidentified animal matter.....	5

This table shows that at least 98 per cent of the toad's food is of animal origin. The vegetable matter (1 per cent) was composed of bits of grass, leaves, rotten wood, etc., evidently swept in by accident along with the insect food. It is in this way, doubtless, that gravel (1 per cent) found its way into the stomachs. The unidentified material consisted of broken parts of insects, animal tissue, etc., which were so finely ground as to be beyond recognition and probably represented injurious species in great part, although not so considered in the table.

The nature of the vegetable and mineral matter found in the stomachs needs no further mention. The animal matter recognized constitutes 93 per cent of the total food, of which 77 per cent was insects and 16 per cent other forms. As might be expected, nearly all the animal matter is composed of terrestrial species or of forms which at some time frequent the ground for shelter or migration.

Worms.—The common angleworm was present in 14 stomachs, principally in toads taken soon after showers, and formed 1 per cent of the total food. Rains drive the worms to the surface, where they fall easy victims to a particularly hungry toad. From studying toads in confinement, it appears that worms are not preferred by that animal as an article of diet, but may be eaten. Worms are of great service in tilling and aerating the soil, as Darwin has so well shown. On the other hand, they often cause great annoyance in greenhouses and in flower beds out of doors. Since the toad frequents the abodes of man, it seems probable that the good done by worms in such localities may well be offset by their damage as above mentioned.

Snails.—Snails are a serious pest in greenhouses and gardens, where their depredations on lettuce and other succulent plants are well known. Several of the large naked snails common in gardens were found in the stomachs, while, in the case of the shell-bearing snails, it was found that the acid stomach juices of the toad were sufficient to dissolve the shell in a short time. It seems a little strange that such slow-moving animals should attract the attention of the toad, yet it is apparent that the animal finds them suitable articles of food, as shown by their constituting 1 per cent of the total stomach contents.

Sow bugs.—These small creatures were most numerous in stomachs taken in the late summer, and made up 2 per cent of the food for the season. Their damage to the roots of orchids, violets, pansies, roses, etc., has been frequently noted by florists. By destroying them the toad renders a distinct service.

Thousand-legged worms.—These form a constant article of diet, as many as 77 having been found in a stomach. Ten per cent of the food of the toad was of this class. They are frequently called "wire-worms," although this name belongs properly to the young of the "click beetles." Farmers often find the attacks of these myriapods on potatoes a serious matter. The late Dr. J. A. Lintner has recorded an instance where for two years in succession a potato crop was severely injured by these "worms." Many cases of injury to newly planted potatoes have come to the writer's attention, while others have recorded the partial destruction of cucumbers, tomatoes, etc., from this cause.

Spiders.—It is not strange that such active creatures as spiders form 2 per cent of the toad's food. Naturally most of the spiders were of terrestrial species. How much good spiders accomplish is an open question, but since they destroy large numbers of flies we have included them in the column of beneficial insects. It should be noted, however, that the spider's web often catches those active parasitic flies which would otherwise serve man through the destruction of injurious caterpillars. Perhaps a fair statement would be that the harm the toad may do by including 2 per cent of spiders in its menu is offset by the 13 per cent of snails, sow bugs, and "thousand legs" which it destroys. This brings us, then, with a clean balance sheet to a consideration of its insect food in the strict sense of the term.

Grasshoppers, crickets, etc.—These insects were found to make up 3 per cent of the food of the toad, and included several of the common species of the hay field as well as house crickets, tree crickets, and cockroaches. The damage to grass and grain crops by grasshoppers is too well known to require more than mere mention. The black house cricket is often a nuisance, while the cockroaches and water bugs are even worse. The small roach or water bug was often found in stomachs of toads taken on city streets. The toad is entitled to unstinted praise for its work in destroying these insects.

Ants.—We come on debatable ground when we take up the economic importance of ants. The writer for the purposes of this paper has regarded them as of neutral value. Most entomological writers regard lightly the shortcomings of these industrious and highly intelligent creatures. Certainly one can not observe their systematic domestic arrangements and evident reasoning powers without a feeling of sincere admiration. During the season of their activities they destroy a certain number of soft-bodied insects and carry off more dead ones as a

provision against future need. On the other hand, they care for and distribute plant lice and certain other related insects, infest lawns, walks, and dwellings, attack cooked food, and often make of themselves an unmitigated nuisance, as many a perplexed housekeeper can attest.

Ants constituted 19 per cent of the total contents of the stomachs examined. The greatest number was found in the May examinations, when they were present in 70 per cent of the stomachs and formed 23 per cent of the food for that month. Aside from ants a few allied insects—such as bumble bees, honey bees, wasps, and hornets—and two ichneumon flies were noted in the examinations. The latter insects are beneficial as parasites on certain caterpillars. Beekeepers have informed the writer of cases where toads had taken position at the entrance of hives, and thus destroyed a large number of bees. This loss might have been avoided by raising the hives above the surface of the ground. Since the toads feed principally at night, such cases are probably of rare occurrence.

Beetles.—There is a certain family of active black or metallic ground beetles, which are usually present in gardens, fields, or woodlands, feeding for the most part on soft-bodied insects, and occasionally varying their diet by attacking low-growing fruits. These ground beetles undoubtedly are beneficial, as a whole, although the damage to strawberries by certain species has caused considerable loss at times. The most serious charge to be laid against the toad is the destruction of these ground beetles, which make up 8 per cent of the total food.

On the other hand, the members of the May-beetle and click-beetle families are commonly present, and furnish 6 and 5 per cent, respectively. The May beetle, or June bug, is unfavorably known as the parent of the white grub, which, in certain years, destroys large areas of grass land and lawns, and also works havoc on the potato crop. Promiscuous shooting of crows has removed one of the principal checks on this insect; hence the service of the toad in this connection is of especial value. The “rose bug,” or rose-chaffer, was found in several stomachs.

The common wireworms, which attack newly planted corn, are the progeny of the click-beetles, and these insects were present in large numbers in the stomachs examined. Wireworms also attack potatoes, lettuce, cabbage, and other garden crops.

Snout-beetles, or weevils, make up 5 per cent of the toad's food. These insects, of which the plum curculio is a good type, are among the most difficult pests to combat. Nearly all have the habit of dropping to the ground and feigning death when disturbed, thus giving the toad a chance to capture them. Among the species found in the stomachs were two specimens of the plum curculio, and many which bore in standing timber and shade trees.

Potato bugs, cucumber beetles, and their allies amounted to 1 per

cent of the total food. The injurious habits of these species need no comment. Of equal rank were the carrion beetles (1 per cent) of possibly beneficial habits, and miscellaneous beetles (1 per cent). The latter, aside from an occasional ladybug (beneficial), are of no special importance. The sole value of the carrion beetles lies in their habit of burying or devouring dead animal matter which might otherwise become offensive.

Cutworms and army worms.—The young or larvæ of moths formed 28 per cent of the total food; cutworms forming 16 per cent, tent caterpillars 9 per cent, and miscellaneous caterpillars 3 per cent. The destruction of cutworms is of special importance. These insects feed by night, and the grower only learns of their presence through the loss of his lettuce, cabbage, and other plants. Hand labor offers the most practical remedy, and this is ably assisted by the efforts of the toad. To appreciate fully the number of cutworms a full-grown toad may consume, one should watch these animals in a field infested by army worms, which are members of the cutworm family. Three toads taken under such conditions contained, respectively, 9, 11, and 55 army worms. These soft-bodied insects are quickly digested, and the toad's capacity for cutworms seems only limited by the supply.

Tent caterpillars.—The insects consumed by the toad are chiefly those of terrestrial habit. Yet the good work of the toad is not confined to insects of this class. There are a large number of caterpillars which feed ordinarily on trees, yet seek the ground when ready to transform, and these fall easy victims to the toad. The common tent caterpillar of the wild cherry and apple well illustrates this point. These caterpillars when full grown often travel considerable distances in search of suitable places for cocoon making.

In May these insects formed 18 per cent of the food, and for the season 9 per cent. This insect is a pest of the first rank on apple trees and occasionally works on cherry, plum, and peach. It is much preyed upon by the cuckoo and oriole, while the toad secures a fair proportion of those that escape the birds. From 15 to 20 were often found in the stomachs, 37 being the largest number noted. The writer once saw a black-billed cuckoo eat 35 of these insects at one meal. That bird is well protected by wise laws. The toad has equally as good a record, but receives no legal protection from wanton cruelty.

Miscellaneous caterpillars.—Among these insects, which formed 3 per cent of the food, were noted such injurious species as the gypsy moth, canker-worm, Vanessa, grape and celery caterpillars, tomato worms, cabbage worms, etc. An abundance of active gypsy-moth caterpillars in certain Massachusetts localities often proves sufficient to tempt the toad from retirement even at midday. Three of the toads' stomachs examined contained, respectively, 7, 15, and 65 gypsy caterpillars. As a means of checking the increase of such a serious pest the value of

the toad is small, but the case is of interest as showing that tree-infesting caterpillars are often captured by this animal.

It would seem that such heavily armored insects as the spiny *Vanessa* caterpillars would escape the toad, yet in spite of their natural protection they are gathered in without apparent discomfort. The damage caused to the elm, willow, and apple by these insects is a matter of common knowledge.

Elsewhere mention has been made of the capture by the toad of the winged brown-tail moths as they fall partially stunned from the street lamps. The lamps have a strong attraction for the moths, and the toad makes sure that few if any escape. This imported European pest has now become well established in several New England States, particularly in residential districts. It is here that the toad is most valuable as a destroyer of the moths. Four toads taken under electric lamps contained 10, 11, 15, and 17 moths, respectively. The caterpillars of this insect are but little more fortunate than the moths. Six toads taken in infested orchards contained, respectively, 3, 3, 5, 7, 8, and 12 caterpillars. When we consider that the hair with which these insect are clothed produces a most intense irritation whenever it comes in contact with the human flesh, it would seem that the toad is practically immune from injuries of this class, and that few if any caterpillars are well enough protected to escape its rapacious appetite once they come within its reach.

ECONOMIC STATUS OF INSECTS DESTROYED BY THE TOAD.

In the following table an attempt is made to strike a balance between the good accomplished by the toad through its ravages on injurious species and the harm it does by destroying beneficial species:

Insect food of the toad classified as regards economic status.

	Benefi- cial.	Neutral.	Injuri- ous.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Cutworms, caterpillars, etc.....			28
Ants.....		19	
Injurious beetles.....			18
Sow bugs, myriapods, snails, etc.....			13
Ground beetles.....	8		
Grasshoppers, etc.....			3
Spiders.....	2		
Carion beetles.....	1		
Worms.....		1	
Vegetable matter.....		1	
Mineral matter.....		1	
Total a.....	11	22	62

^a The 5 per cent unidentified has been excluded from this classification.

To summarize: Against the toad must be reckoned the destruction of many beneficial ground beetles, a few spiders, an occasional carion beetle, ladybird, and ichneumon fly, forming as a whole 11 per cent of its food.

To the credit of the toad we must place the destruction of a remarkably large number of particularly injurious insects, such as cutworms, army worms, caterpillars, gypsy moths, brown-tail moths, May beetles, rose-chafers, wireworms, cucumber and potato beetles; also snails, thousand-legged worms, and sow bugs. The quantity of injurious species destroyed forms 62 per cent of its total food. Should ants be included as injurious, as many housekeepers would think proper, this figure would be increased to 81 per cent. These figures, derived from careful examinations, show the toad to be a highly beneficial animal and well entitled to man's protection in every possible way.

THE TOAD'S CAPACITY FOR GOOD.

The amount of food consumed by the toad is remarkable. Elsewhere records have been given of finding 77 thousand-legged worms in one stomach, 37 tent caterpillars in another, 65 gypsy moth caterpillars in a third, and 55 army worms in a fourth. Under the writer's direction, 24 medium-sized gypsy moth caterpillars were fed to a toad under observation before its appetite was appeased, while Mr. F. H. Mosher fed over 30 full-grown celery caterpillars to another in less than three hours. Doctor Hodge has seen a toad "snap up 86 house flies in less than ten minutes," while he has also published an interesting observation by Ellen M. Foskett, Worcester, Mass., who fed 90 rose bugs to a toad without satisfying its appetite.

The number of insects a toad consumes in a season is conjectural. The writer is satisfied that the amount of food taken in twenty-four hours amounts to about four times the stomach capacity. In cold weather this figure would be lower, while in midsummer, when insect life is at its height, the quantity would probably be larger. A typical stomach examination as taken from the writer's notes is given below.

Specimen 43, taken 9 p. m. May 11, 1896:

	Per cent by bulk.
6 cutworms	50
5 thousand-legged worms	20
6 sow bugs	20
9 ants	6
1 weevil	2
1 ground beetle	2

On the basis of the above data the amount of food consumed in certain periods would stand as follows:

Numbers of insects which one toad may destroy.

Period.	Cutworms.	Myriapods.	Sow bugs.	Ants.	Weevils.	Ground beetles.
24 hours	24	20	24	36	4	4
30 days	720	600	720	1,080	120	120
90 days	2,160	1,800	2,160	3,240	360	360

In ninety days (a period selected because May, June, and July represent the time of the toad's greatest activity) it would destroy 360 beneficial insects (ground beetles) and 9,720 injurious or noxious insects. Take the single item of cutworms. These insects are preyed upon by ground beetles. Let us assume that the ground beetles, if spared, would have succeeded in capturing 10 per cent of the cutworms. This would leave a net balance of 1,944 cutworms to the toad's credit. Many gardeners give their children one cent apiece for each cutworm found and destroyed, considering this a low estimate of the damage caused by the insects. Even at this nominal figure, without considering the importance of the destruction of other injurious insects, the toad's services on this one item would figure \$19.44.

NATURAL ENEMIES OF THE TOAD.

The toad suffers from enemies both natural and unnatural. Of those provided by Nature a few internal parasites are sometimes found, while hawks, owls, crows, snakes, and skunks yearly destroy large numbers. The marsh hawk kills a great many toads during the spawning season, while hens, ducks, geese, and guinea fowls feed on the young toads as they migrate from the breeding pools.

It is perhaps the irony of fate that large numbers of the toad should be killed annually by man, the one most benefited by its life. Lawn mowers work great slaughter among them, while the practice of burning over lawns and fields kills more. The killing of toads in this way is largely unnecessary and the extra labor involved in protecting their lives will be more than repaid by their services.

The heaviest charge of wrongdoing must be entered against the small boy, ubiquitous, inquisitive, and often thoughtlessly cruel. In a case coming under the writer's notice two boys in one afternoon established the disreputable record of 17 dead and mutilated toads captured at a breeding pool. Such a wanton and expensive exhibition of cruelty may be unique, but it is certain that thousands of toads are killed in this way annually, and this practice will continue until our boys are taught to recognize the value of the toad and to respect its rights. Laws protect our insectivorous birds as well as others whose worth to man is, to say the least, a debatable question. The toad's worth is an established fact. Should it not receive a similar protection?

HOW THE TOAD MAY BE MADE USEFUL.

Elsewhere reference has been made to the strong homing instinct of the toad. This makes it difficult to establish toad colonies unless the animals are brought from a considerable distance. It is said that English gardeners often pay as high as \$25 per hundred for toads for colonizing purposes. That such a procedure is sometimes successful

is shown by the experience of the well-known authoress, Celia Thaxter, who at one time found her beautiful gardens at the Isles of Shoals overrun by insects and snails. A considerable number of toads were imported from the mainland, with the result that in a short time the pests were suppressed and the flowers preserved from harm.

A better plan is to provide a breeding place for toads and carry them to it at the mating time, so that later in the season the young toads leaving the water may establish themselves in the locality. A shallow pool having a small but constant water supply is all that is needed. Stagnant rather than running water is desirable, since the growths in which the tadpoles feed do not develop so well where there is a current. Further, the stagnant pools usually have a higher temperature, thus favoring the growth of the tadpoles. Against this plan may be urged the breeding of mosquitoes in such pools, and under some circumstances this objection may prove an important one. It is entirely possible, however, that the tadpoles would keep down the mosquito larvæ, and in any case the young toads will leave the water by mid-summer or before the mosquitoes become abundant, when the pools may be drained.

It is always well to provide artificial shelters for toads in gardens. These are easily made by digging shallow holes and partially covering them with a board or flat stone. Toads will use these shelters for weeks, sallying forth by night and returning at daybreak. Greenhouse owners will find toads particularly useful as destroyers of snails, sow bugs, weevils, and other injurious forms of animal life. The well-known entomologist, Dr. Ritzema Bos, writes: "In the research garden of the Rouen entomological laboratory the snails were entirely exterminated in 1891 as a result of introducing 100 toads and 90 frogs." At Malden, Mass., a collection of valuable orchids were severely injured through the attacks of myriapods and sow bugs. On the writer's advice a number of toads were introduced and all damage from this cause soon ceased. Many other cases where the toad may be made useful will suggest themselves. The common greenhouse rose weevil (Fuller's beetle) can doubtless be controlled in greenhouses by aid of toads, particularly if the beetles be jarred from the bushes at occasional intervals.

THE STUDY OF THE TOAD.

"Go to the ant, thou sluggard," was Solomon's dictum. One may find profit and pleasure in studying any of the common forms of animal life, but few offer a more attractive field than the subject of this paper. Abundant everywhere, harmless, easy to obtain and rear, the toad is one of the best objects for class-room work in nature study. A small aquarium and a pair of toads or a mass of toad's eggs are all that are required. Let the aquarium be of glass, earthenware, or

wood, shallow, and supplied with plenty of water plants, a few fresh-water clams or mussels to keep the water in circulation, and a small quantity of dog biscuit or chopped fresh meat if needed when the tadpoles are half grown. Care must be taken not to supply more meat than they will devour, since otherwise the water may become fouled. Such an aquarium makes an object of unfailing interest in the school-room or home, and by summer will yield hundreds of small toads for colonizing gardens and farms. The value of such a study to the children can not be overestimated.

U. S. DEPARTMENT OF AGRICULTURE.

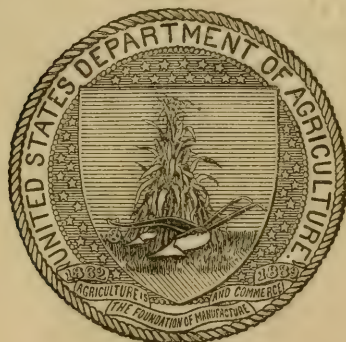
FARMERS' BULLETIN No. 209.

CONTROLLING THE BOLL WEEVIL IN COTTON SEED AND AT GINNERIES.

BY

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LETTER OF TRANSMITTAL

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., September 16, 1904.

SIR: I herewith transmit a manuscript by Mr. W. D. Hunter, special agent of this Bureau in charge of the experimental work with the Mexican cotton boll weevil in Texas. The subject investigated in this paper is one of the very greatest importance to the cotton interests in the South, namely, the control of the boll weevil in cotton seed and at ginneries; and on account of the fact that the ginning season is now at its height and that the farmers in Texas and Louisiana will soon be obtaining seed for planting purposes, I recommend the immediate publication of this paper as a Farmers' Bulletin.

Respectfully,

L. O. HOWARD,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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CONTROLLING THE BOLL WEEVIL IN COTTON SEED AND AT GINNERIES.

COTTON SEED AND GINNERIES AS FACTORS IN THE SPREAD OF THE BOLL WEEVIL.

The extent to which cotton seed and ginneries are factors in the dissemination of the boll weevil has not been realized generally. During the present season the Bureau of Entomology has paid particular attention to this matter and has demonstrated that ginneries are the most important single factors in disseminating the pest. At least in regions where the cotton fields are somewhat isolated, spreading of the insect by flight, aided by the wind, seems to be of little importance compared with this artificial agency. The cooperation of this Department with the Louisiana crop pest commission, which is engaged in an attempt to prevent the further entrance of the weevil into that State, has given many opportunities for determining the exact means whereby weevils reach new regions. At the present time this work has led to the conclusion that if it were possible to control the pest at gins, it might be possible to greatly retard its present rate of spreading, but that without any such means of control there is great doubt about the feasibility of an attempt to check its spread, unless, indeed, measures are taken to prohibit in uninfested localities the ginning of cotton from infested regions. Early in the season of 1903 five trained men connected with this Bureau were stationed in the western parishes of Louisiana. The infested fields have been determined very carefully, and a special study has been made of the means by which they became infested. It was soon found that Texas cotton growers along the Sabine River were accustomed to ginning their cotton in Louisiana. Various localities in the eastern tier of counties in Texas have been infested for nearly two years. One farmer by bringing seed cotton from Texas to Louisiana gins would cause those gins to become infested. From these infested gins the spread of the weevil has been traced carefully. In some cases customers of an infested gin changed to an uninfested one during the season and thus carried weevils with them. Instances have also been recorded where farmers collected seed from uninfested cotton on wagon sheets at a gin where

infested cotton had also been ginned. In these cases no infestation has been attributable to the seed so collected. In one case, however, a farmer was known to have collected the seed on a sheet in the way described, and during the present season it was found that the only field on his farm where the weevil is found was that to which he had hauled bulk seed for fertilizer from the same gin at which he had so carefully guarded his cotton seed. One farmer in Calcasieu Parish ginned his cotton partly at an infested and partly at an uninfested gin. It has been found that the weevils upon his plantation occur only in the fields grown from seed brought from the infested gin.

In a sparsely settled country, like the western portion of Calcasieu Parish, where the cotton fields are small and the gins consequently located at considerable distances from one another, the weevils have been carried astonishing distances. Prof. H. A. Morgan, secretary of the Louisiana crop pest commission, has furnished the writer with many interesting examples of this. In one case it has been ascertained that a farmer in the neighborhood of Merryville transported the pest for 16 miles, thus establishing an isolated infestation. That the occurrence of the pest in this locality was not due to its being blown by the wind is demonstrated by the fact that no other cotton fields in the neighborhood are infested, the neighbors having ginned their cotton outside of the infested territory.

In Shelby County, Tex., a dozen farmers procured seed of a desirable variety of cotton, which, though grown in the immediate uninfested locality, had been ginned farther west, where the weevils were very numerous. On the dozen farms upon which this cotton is growing the present season weevils have invariably been found, although surrounding fields planted from seed that was ginned in the immediate neighborhood have been found to be uninfested.

CONTROL OF BOLL WEEVIL IN SEED BY FUMIGATION.

As soon as the facility with which the boll weevil is disseminated in cotton seed was understood, the Bureau of Entomology devoted considerable attention to the possibility of destroying the pest by fumigation.^a Only two gases seem to be at all suitable for this purpose. These are carbon bisulphid and hydrocyanic acid gas, the consensus of opinion among entomologists favoring the former as a fumigant for stored grains. Both of these gases have their drawbacks. As against the danger from the inflammable and explosive properties of carbon bisulphid, there is the danger to human life by the careless use of hydrocyanic acid gas. Experiments by Hicks and Dabney, of the

^a Dr. A. W. Morrill and Mr. W. W. Yothers assisted in the fumigation experiments. In these experiments, as well as in all the work leading to the present bulletin, the writer was very materially aided by his principal assistant, Dr. W. E. Hinds.

Division of Botany of the Department of Agriculture, with carbon bisulphid, and Townsend, formerly of the Maryland Experiment Station, with hydrocyanic acid gas, show that the germinating power of the seed would not be lessened by treatment with either of these materials. As a matter of fact, numerous experiments that have been performed in connection with the present work have fully substantiated the results obtained by other investigators.

Carbon bisulphid seems to be much cheaper for use in the fumigation of cotton seed than is hydrocyanic acid gas. The former at the rate of $1\frac{1}{2}$ pounds per 1,000 cubic feet would cost about 15 cents for 1,000 cubic feet, while for fumigation for the same space with hydrocyanic acid gas at least 10 ounces of potassium cyanide would be required. This would cost about 25 cents, to which must be added about $2\frac{1}{2}$ cents for the sulphuric acid, bringing the cost up to nearly twice as much as in the case of the former fumigant. Mr. C. L. Marlatt and others have remarked about the greater resistance of weevils to hydrocyanic acid gas than to carbon bisulphid. These observations have been fully verified in the case of the boll weevil by investigators who have conducted the work.

FUMIGATION EXPERIMENTS.

In order to test the relative adaptability of these gases, and to determine the conditions under which they may be used effectively, a number of experiments were performed.

Experiment with hydrocyanic acid gas.

Rate per cubic foot.	Distance of weevils from surface.	Time.	Results.	Remarks.
<i>Grams.</i>	<i>Inches.</i>	<i>Hours.</i>		
0.25	8 to 10	3	Alive	A fly killed. A fly alive. Do.
.25	12	3	do	
.30	3 to 4	5	do	
.30	6 to 8	5	do	
.30	12	5	do	
.50	0	5	Dead	
.50	6 to 8	5	Alive	
.50	8 to 10	5	do	

In this experiment weevils in tin boxes, perforated in such a manner as to allow the free access of the gas, were buried at varying depths in sacks containing 100 pounds of cotton seed. The sacks were inclosed in a specially prepared tight box. The cyanide was lowered into the sulphuric acid through a small orifice in the lid.

As will be noted, the hydrocyanic acid gas, in a strength twice as great as is successfully used for the fumigation of grain, in a treatment of five hours did not kill boll weevils covered by from 6 to 10

inches of cotton seed. The failure of a heavy application of the gas to kill house flies covered by from 6 to 12 inches of seed in five hours shows the great resistance of bulk cotton seed to the uniform diffusion of hydrocyanic acid gas. It was consequently considered that there was not a promising outlook for this gas on account of its very slight penetrating power, and attention was directed to carbon bisulphid.

Experiment with carbon bisulphid in box of 15.88 cubic feet capacity.

Rate of CS ₂ per 1,000 cubic feet.	Distance of weevils from sur- face.	Time.	Results.
<i>Pounds.</i>	<i>Inches.</i>	<i>Hours.</i>	
1½	8 to 10	24	Alive.
1½	12	24	Do.
3	8 to 10	24	Do.
3	12	24	Do.
3	6	24	Dead.
3	12	24	50 per cent alive.
4	8 to 10	24	Alive.
4	12	24	Do.
5	8 to 10	24	50 per cent alive.
5	12	24	Alive.

This experiment was performed in a tight box, in which were placed sacks of cotton seed containing weevils in perforated tin boxes buried at varying depths, as in the preceding experiment. The amount of carbon bisulphid used was varied from 1½ pounds per 1,000 cubic feet, a rather heavy application for the destruction of insects in stored grain, to 5 pounds per 1,000 cubic feet. It will be noted that the insects covered by 10 or more inches of seed were not killed in twenty-four hours, even with the heaviest application. However, it was considered advisable to verify these results by another experiment, as follows:

Experiment with carbon bisulphid in cylinder 70 inches long.

Rate of CS ₂ per 1,000 cubic feet.	Distance of weevils from sur- face.	Time.	Results.	Remarks.
<i>Pounds.</i>	<i>Inches.</i>	<i>Hours.</i>		
3.0	6	24	Dead	House fly killed.
3.0	64	24	Alive	
7.3	36	37	Dead	
7.3	64	37	Alive	
10.0	36	21	Dead	Do. Do.
10.0	54	21	Alive	
10.0	64	21	do	

This experiment was performed in an upright, gas-tight, galvanized-iron cylinder 70 inches long by 12 inches in diameter, in order to obtain conditions similar to those existing in the case of cotton seed stored in bulk or in bins. The carbon bisulphid was placed in a shal-

low dish on top. Both the top and bottom of the cylinder were provided with leather packing and covers which were screwed on tight. The weevils were inclosed in perforated boxes as in the preceding experiments. The results show the failure of the gas, when applied at the rate of 10 pounds to 1,000 cubic feet, to penetrate sufficiently to kill weevils buried beneath $4\frac{1}{2}$ or more feet of seed. At 3 feet, however, 7.3 pounds per cubic foot killed the insects. That small quantities of gas penetrated the full depth of the cylinder is shown by the death of the house flies.

These experiments seemed to indicate the futility of the use of carbon bisulphid in an unvolatilized form, and it was therefore determined to test it in an artificially volatilized form, as shown in the following experiments. Credit for this idea should be given to the writer's principal assistant, Dr. W. E. Hinds, who has experimented extensively with carbon bisulphid.^a

Experiment with carbon bisulphid volatilized artificially in cylinder 70 by 12 inches.

Rate of CS ₂ per 1,000 cubic feet.	Distance of weevils from surface.	Time.	Results.
<i>Pounds.</i>	<i>Inches.</i>	<i>Hours.</i>	
4	48	24	Dead.
4	64	24	Do.
5	48	15	Do.
5	64	15	Do.
10	36	16	Do.
10	54	16	Do.
10	64	16	Do.

In this experiment, by means of special apparatus, a current of air was passed through the liquid carbon bisulphid and the resulting vapor was driven through connecting tubing into a section of iron gas pipe which could be forced through the seed to the bottom of the cylinder, and which was gradually withdrawn during the application. The diffusion of the vapor under pressure through the mass of seed was very rapid and, as will be noted by a comparison of the two last tables, the amounts of carbon bisulphid used were far more efficient.

This experiment was followed by a number of others in forcing the gas into the seed in 100-pound sacks. It was found quite practicable in this way to kill the weevils contained at any point in the sacks, providing the carbon bisulphid was used at the rate of 8 pounds per 1,000 cubic feet and left for forty hours.

MEANS AND METHOD FOR SUCCESSFUL FUMIGATION OF COTTON SEED.

The following plan for this work is proposed: A tight matched-board box should be provided having sides 4 feet high, open on top,

^aSee Farmers' Bulletin No. 145. U. S. Dept. of Agr.

and of other dimensions to accommodate 12 or more 100-pound sacks of cotton seed placed upright upon the bottom. Another tier of sacks could be added if desired. Into each one of these sacks about 1 ounce of carbon bisulphid should be forced by an apparatus for volatilizing the liquid and mixing the vapor with air. The accompanying illustration (fig. 1) will give an idea of this apparatus. It should consist of

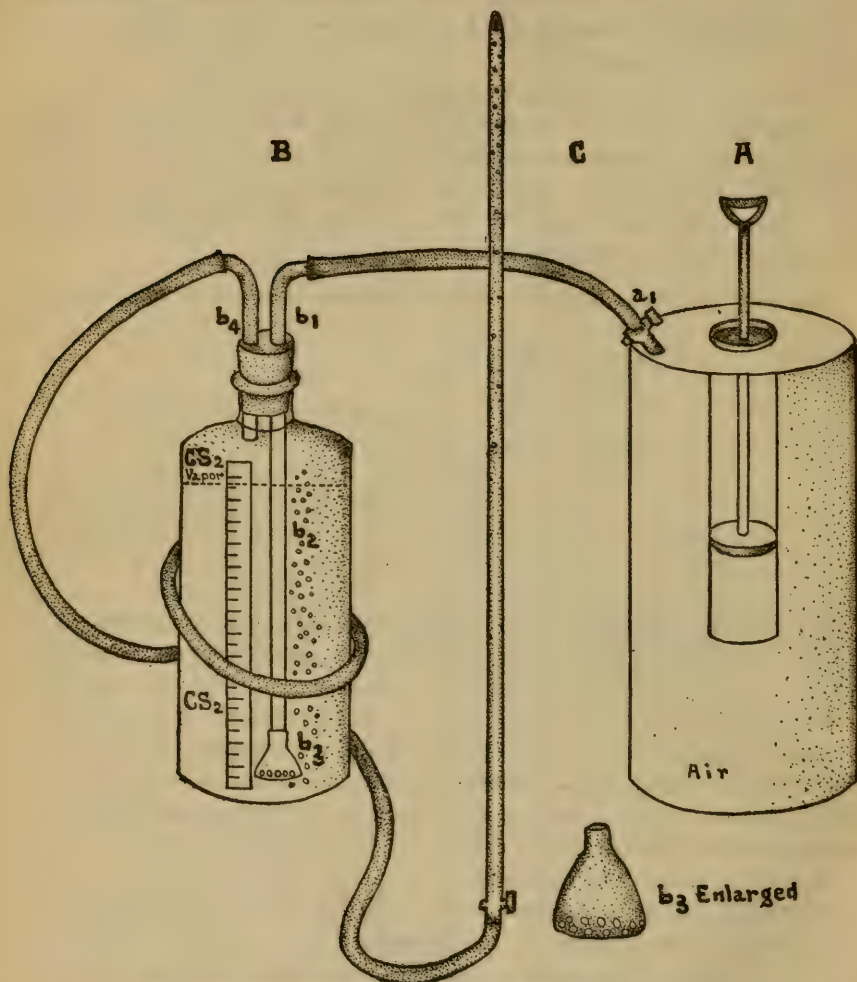


FIG. 1.—Apparatus for fumigating cotton seed in the sack. (Original.)

three essential parts, as shown in the illustration. *A* is an air pump having sufficient storage capacity to enable it to maintain a steady discharge of air for several minutes without continuous pumping. The stopcock at *a¹* regulates or prevents the escape of air, as may be desired. *B* is an ordinary 2-quart bottle, fitted at *b¹* with a tight

stopper of good length, having two openings, through which the inlet and outlet pipes pass. These pipes may be of glass or metal and should be as large as can be used. The inlet pipe, b^2 , reaches nearly to the bottom of the bottle and is provided at the lower end with a perforated metal cap as large as will pass through the neck of the bottle. This allows the escape of the air in small bubbles and insures rapid evaporation. The outlet pipe, b^4 , reaches only through the stopper. Upon the outside of the bottle is pasted a paper marked with 1-ounce graduations. C is a piece of ordinary $\frac{3}{8}$ -inch iron gas pipe about $3\frac{1}{2}$ feet long, but this may be any desired length. It is closed and roundly pointed at the tip, and for about 15 to 18 inches of its length provided with small perforations pointing in all directions to give free escape to the vapor into all parts of the sack of seed at once.

The connections may be of rubber tubing, but as little rubber as possible should be used for this apparatus, as it is affected by the vapor of the bisulphid, and the couplings will have to be frequently replaced. This, however, will not be a considerable item of expense. With the apparatus just described, one operator would be able to accomplish the entire work of disinfection. The amount of carbon bisulphid recommended is about 1 ounce for each 3-bushel sack. It is safe to say that this can be secured for less than 1 cent per ounce when purchased in 25 or 50 pound lots, making the cost of bisulphid not over 1 cent per sack. As it requires but from two to three minutes to vaporize 1 ounce of the liquid in the manner described, the expense for labor in application would not amount to one-half a cent per sack. Fumigation with carbon bisulphid can therefore be effectively made at the slight expense of from 1 to $1\frac{1}{2}$ cents per 100-pound sack.

Application of the bisulphid in this manner reduces the elements of danger to a minimum, as the vapor is almost wholly confined and the slight quantity escaping, mixed with the open air, would not be in either inflammable or explosive proportions. It has been determined that the slight trace of bisulphid vapor in the air would not injure the operator in the slightest degree. The sacks should be left in the box for forty hours after the gas is injected.

SUMMARY OF RESULTS OF FUMIGATION EXPERIMENTS.

I. The fumigation of cotton seed in bulk offers many difficulties. The adhering lint seems to form a dense mass very impervious to the commonly used fumigants. Moreover, the boll weevil seems unusually resistant to these agents.

II. At present it does not seem possible to use hydrocyanic acid gas. Especially susceptible insects, like house flies, when protected by from 6 to 12 inches of seed, are not killed within five hours by a gas resulting from the use of 0.5 gram of potassium cyanide to the cubic foot.

III. Carbon bisulphid allowed to volatilize naturally is of little use. At the rate of even 10 pounds per 1,000 cubic feet it will not kill weevils buried beneath $4\frac{1}{2}$ feet or more of seed. At the rate of 4 pounds per 1,000 cubic feet simply poured into a 100-pound sack it will not always kill the weevils at the bottom. It is consequently useless in this way for the fumigation of seed in large bulk.

IV. When volatilized artificially, however, carbon bisulphid may be used successfully in destroying the weevil in sacked cotton seed by means of a comparatively cheap and simple apparatus. Every farmer living in an uninfested region who obtains cotton seed from infested parts should insist that it be fumigated in this way. The introduction of the weevil into foreign countries could be prevented in the same way.

CONTROLLING THE BOLL WEEVIL AT GINNERIES.

On account of the great difficulty of destroying the boll weevils by means of the fumigation of the bulk seed, which was demonstrated by the foregoing experiments, the Department has concerned itself especially with an investigation to determine whether or not it is possible to prevent the dissemination of the pest through the agency of gins. The services of an especially trained gin expert, Mr. James Hull, who has been actually engaged in the ginning business in Texas for fourteen years, were obtained. He has made a careful study of all the various systems of ginning cotton in this country, with special reference to the boll weevil. The suggestions offered in the following pages are based upon his work. They have, moreover, been brought to the attention of representatives of the principal ginning systems for suggestions as to their practicability. Circulars have been addressed to the 11,000 ginners in Texas and Louisiana in order to obtain an exact knowledge of the various systems and combinations in use, in order that the Department's suggestions may not be out of place in view of the machinery that is in actual use.

EXPERIMENTS TO DETERMINE EFFECTS OF MACHINERY ON LIVE WEEVILS IN SEED COTTON.

In addition to the foregoing basis for this report, a modern gin has been run experimentally to determine several previously unsettled points regarding the exact places in the system of ginning and handling cotton through which the weevils may escape. The first of these experiments was made to determine whether the weevils could pass alive through the main fan in a pneumatic elevator system. Several hundred live weevils, marked with colored pencils in such a manner as to be easily recognizable, were fed into the suction tube between the gins and the fan, after a large bag about $2\frac{1}{2}$ feet in diameter and 16

feet long had been tied over the mouth of the discharge pipe in the car standing on the sidetrack. In this particular instance the fan was of 44-inch size and was run at 1,800 revolutions per minute. A careful examination was made of the contents of the bag, but it was found that no weevils passed through alive. The weevils were cut into small fragments by the swiftly revolving blades of the fan.

A second experiment was designed to determine whether weevils might pass through the gin itself when in actual operation. One hundred and fifty marked live weevils were fed directly into the outer roll of an 80-saw gin, revolving at the rate of 400 revolutions per minute. The first seed, run through in about one minute, was collected and examined separately. Then the whole roll was thrown out after about two minutes. The mote dust was also collected and examined. The seed run out during the first minute yielded 47 marked weevils alive and 3 marked weevils dead. The main bulk of the roll contained about 15 times as much seed as collected in the way just described. It yielded 40 marked weevils alive and 5 marked weevils dead. The mote collection yielded 10 marked weevils alive and no marked weevils dead. The total number of marked weevils collected in this experiment was 105; the percentage of marked weevils recovered was 70; the percentage of recovered marked weevils alive, 92.4, and the percentage of recovered marked weevils dead, 7.6. A number of unmarked weevils which had evidently passed through the pneumatic feeder to the gin breast were found in the course of this experiment. They are, of course, omitted in the above figures.

This experiment, which was repeated at different times, demonstrated that in actual ginning weevils escape from the gin at two points, one with the seed into the seed chute and the other with the motes at the mote board.

The following experiments demonstrated the fact that in addition to the two avenues of escape that have been mentioned weevils also pass through cleaning feeders, in many cases without being injured. A lot of 200 live weevils, marked as above described, was run through a modern cleaner feeder, consisting of fluted rollers, picker roller, and the accompanying screens. In this case the picker roller was run at about 170 revolutions per minute. The weevils were fed into the top of the cleaner feeder at the point where the cotton becomes dead. The trash from the spiral conveyor tube was collected for about ten minutes, as was also the seed discharged by the gin during that time, in addition to the motes. Results: Marked weevils extracted by cleaner feeder, alive 54, dead 7, total 61; in the seed thrown out, marked weevils alive 6, dead 5; among the motes, marked weevils alive 9, dead 5; total marked weevils found, 86, or 43 per cent of those put in. As in the preceding experiment a number of unmarked weevils were found.

Considering the total (including unmarked weevils) of 124 weevils found, the cleaner feeder separated 71 per cent of the total number. Weevils in the seed numbered 16, or 13 per cent of the total found. In the motes 20 weevils were found, or 16 per cent of the total. Among 88 weevils from the cleaner feeder 83 per cent were alive. Among 16 weevils from seed 56 per cent were alive. Among 20 weevils from motes 55 per cent were alive. Fifty-seven per cent of the marked weevils could not be accounted for.

Summary of experiments in passing weevils through gin machinery.

Nature of experiment.	Method of recovery.	Number of marked weevils used.	Found alive.		Found dead.		Per cent lost.
			Num-ber.	Per cent.	Num-ber.	Per cent.	
Passage through fan only.	Blown on sheets spread in seed house.	105	0	-----	30	29	71
Do.....	Bunting bag at discharge in car.	100	0	-----	90	90	10
Passage through saws only.	Seed caught on floor. No motes.	50	19	38	10	20	42
Do.....	Seed caught on floor. Motes examined.	150	97	64½	8	5½	30
Through cleaner feeder and motes.	Trash and motes ^a collected and examined.	250	55	34	9	3.6	62.4
Through cleaner feeder and saws.	Trash, ^b motes, and seed collected and examined.	200	69	34.5	17	8.5	57

^a Of 94 weevils (dead and alive) recovered, 13 (10 dead and 3 alive) were at mote board.

^b Of 86 weevils (dead and alive) recovered, 11 were found in seed, 14 in motes, and 61 in trash from cleaner feeder.

WHAT THE EXPERIMENTS HAVE DEMONSTRATED.

From the above-described experiments and many observations it has been demonstrated that seed cotton carried by the powerful suction of the fan may strike directly against the wire-screen separator and the weevils contained may not be injured in the slightest degree. These same weevils may be again taken with this same seed cotton from the storage house and driven against another distinct wire-screen separator in the pneumatic system. Thence they may pass down through the screens at the rear of the picker roller in the cleaner feeder and may be carried along with other foreign substances separated from the seed cotton by the screw conveyor connected therewith. In case the insects pass through the screen in the pneumatic elevator chute they pass through the main fan and are killed. In case, however, they are not separated from the cotton by the picker roller in the cleaner feeder they may pass through the saws of the gin with the seed into the seed chute, or drop with the motes from the mote board.

PRESENT SYSTEMS OF HANDLING AND GINNING SEED COTTON.

In the following pages, practically all of the methods of handling and ginning seed cotton in use in the United States at the present time will be discussed, with a view to pointing out the weaknesses of the

several systems in regard to destroying or controlling the boll weevils. The matter is a rather complicated one, owing not only to the diversity of the different systems of ginning the staple, but the frequent combination in one plant of parts of these different systems. Moreover, there is at present considerable activity in the improvement of ginning machinery, resulting in frequent important changes. This discussion, however, will enable any ginner, no matter what his system, to learn the exact point at which the weevils escape, and will consequently show him in what manner the danger of disseminating the pest may be avoided. Moreover, several new suggestions in regard to special cleaners are made in the following pages, and it is hoped that manufacturers and ginnermen will be able to make use of them.

HAND SYSTEM AT SEED-COTTON STORAGE HOUSE.

This class of storage house is used principally in localities where ginning for custom is done exclusively, where farmers desire to bring a portion of a load of cotton at a time, allowing it to accumulate until it amounts to a bale or more, and at large ginneries during the latter part of the season when the gins are not running full time. The seed cotton is placed in bins without any special machinery whatever. At gins where the seed cotton is unloaded by this system it appears that all boll weevils must pass with the seed cotton into the gin house. The ginner must therefore depend upon devices in the gin house proper, to be described later, for separating weevils from the seed cotton. It is therefore unnecessary to enter into details of unloading seed cotton by hand. We may take up the more modern systems of unloading by mechanical devices, which keep the boll weevils under more or less control.

CARRIER SYSTEM OF UNLOADING SEED COTTON INTO STORAGE HOUSE.

This system consists of an endless apron running from the wagon to the bins. It was in use previous to the advent of the more modern method of blowing seed cotton to the storage house or to its various compartments. As far as the control of the boll weevil is concerned it does not differ from the hand system.

SUCTION SYSTEM OF CONVEYING SEED COTTON FROM WAGON TO STORAGE HOUSE.

This system can be conveniently presented under three heads: (1) With safety fan; (2) with one fan and vacuum box; (3) with two fans and vacuum box.

With safety fan.—In the safety-fan system the seed cotton is drawn from the wagon by suction, and is separated from the air current by a screen within the fan. The blast from the fan is used to blow the

seed cotton into any desired portion of the storage house. In this system, a few boll weevils may be killed by striking against the screen. Those that pass through the meshes of the screen are forced through the fan, where they are undoubtedly destroyed. It is safe to say, however, that the majority will pass along with the seed cotton.

With one fan and vacuum box.—According to the second plan an ordinary fan is used. The seed cotton is drawn from the wagon by the suction of the fan, and separated from the air inside the vacuum box by means of a wire screen. The balance of the operation is the same as in the preceding case, except that a sand pocket is provided at the rear of the screen, thus allowing a large portion of the *débris* to fall into this chamber, where it is prevented from passing through the fan. The accumulated *débris* is usually cleaned out at frequent intervals and thrown about the gin yard, liberating any weevils that may have passed through the screen, as in the preceding case. Though some weevils may be killed by the action of the fan, the great majority of them pass along with the seed cotton.

With two fans and vacuum box.—According to the third plan, the vacuum box provided, as in the preceding case, is connected with two ordinary fans, the first of which is used for suction and the second for blowing the seed cotton into any desired portion of the storage house. From the standpoint of controlling the boll weevil this arrangement has no special advantage over the preceding one.

The vacuum box is frequently used as a cotton dropper. In such cases the seed cotton is dropped directly into a feeder standing beneath it. If this feeder were fitted with the cleaning attachments, to be described later, an excellent means would be provided for destroying many of the weevils that would otherwise pass to the cotton-seed storage house.

Special droppers.—In addition to the above-described system, some concerns manufacture special droppers which pass the seed cotton over a large screening surface before it becomes dead and falls upon the floor or is blown into compartments. The *débris*, which may include weevils, extracted during the movement of the seed cotton over the screen, passes through the fan, by the action of which the insects would undoubtedly be destroyed. Such devices are useful in reducing the number of weevils in the seed cotton before it reaches the gin house proper, but none of them can be depended upon to eliminate all of the weevils. Their work would be much more effective if they were provided with beaters, or a series of beaters, to throw the seed cotton against the screen, thus separating every one of the locks. Undoubtedly one of the most important suggestions to be offered is that more extensive use be made of these devices. The more seed cotton can be agitated, the greater the probability that the

weevils will be removed, and when the débris is passed through the fan, there is no probability that any insects will escape alive.

HAND AND BASKET METHOD AT GIN HOUSE.

In this system the seed cotton is unloaded directly from the wagons into baskets and placed in the feeder. The feeding is accomplished by the movement of an inclined carrier belt which moves the cotton forward and against the picker roller which separates the locks and drops them directly into the gin breast. A considerable amount of sand, gravel, and in many cases weevils, is separated from the seed cotton and dropped either directly upon the floor or into the trash box at the lower portion of the hopper. As a rule the trash, including weevils, is thrown into the seed conveyors, whence it reaches the seed boxes or cars. It will be readily seen that weevils are practically unrestricted by this system, although the collection and destruction of the trash instead of returning it to the seed would eliminate a large number of them. The hand and basket method of feeding the gins is in use at nearly 9 per cent of the ginneries in Texas and at $44\frac{1}{2}$ per cent of those in Louisiana.

PNEUMATIC SYSTEM WITH BELT DISTRIBUTORS.

In this system the seed cotton, either from the wagon or the storage house, is drawn by suction from the fan or driven by a blower against a wire screen. The fan or blower is placed in various positions in the gin house. The wire screen in the separator is the most essential part of the apparatus. Its use is to separate the dirt from the seed cotton and to prevent the seed cotton from passing through the fan and being discharged either into the open air above the building or below into the receptacles for seed. Some manufacturers have provided a box for catching the trash at the rear of the screen or beneath the distributor belt. The seed cotton is dropped upon the distributor belt and deposited in hoppers and open feeders resting horizontally upon the gins. The amount of seed cotton fed upon the belt is to some extent uncontrollable. When all the hoppers are filled a surplus accumulates. This surplus seed cotton drops upon the floor and is from time to time drawn up by suction into the vacuum box or separator, whence it again reaches the distributor belt.

In the distributor-belt system the seed cotton is dropped into an open feeder, which is a convenient term for differentiating feeders used with this system from those used with the pneumatic system, in which all seed cotton and mechanical devices for cleaning it are entirely inclosed. There are many different styles of these feeders, but the essential point for the present purpose is that they are all open. The

bottom of the hopper of these feeders consists of an endless movable apron which carries the seed cotton forward and against the picker roller or spiked drum which separates the loose locks and deposits them in the gin stand. In this class of feeders all of the trash, boll weevils, immature locks of cotton, etc., which does not fall through the picker roller is carried with the seed cotton and falls directly into the gin breast. At the present time it may be safely stated that nearly all the residue which falls between the spikes of the picker roller is swept from the top of the gins and deposited in the seed conveyor, through which it is blown or otherwise conveyed into the seed storage house, cars, or farmers' seed boxes. The spread of weevils is facilitated by the use of this class of open feeders with the distributor-belt system, though the apparatus as in use at the present time has considerable advantage over the hand and basket system. The principal advantage is that the seed cotton is elevated by suction and beaten directly against the separator screen, where a certain number of weevils may be killed. That the number thus killed or removed is small has been proven by many observations. An important suggestion in connection with these open feeders is that a receptacle should be furnished for catching the débris which falls from the picker roll. This trash could easily be carried to any desired point by a spiral conveyor.

The most important weakness in the belt-distributor system is found in the overflow that accumulates on the floor at frequent intervals. Many weevils in the seed cotton thereby have a chance to escape to any part of the ginhouse. This danger is obviated altogether in the system next to be described.

It is needless to state that from the ginner's standpoint, manufacturers have obtained perfection in this system. The present objection could be obviated, to some extent at least, if the overflow from the distributor belt were fed into a weevil-proof box or bin, whence it might be re-fed directly into the gins or into cleaner feeders connected therewith. There are, no doubt, mechanical difficulties to be overcome in making this change, but at present it appears that they are not insurmountable.

PNEUMATIC SYSTEM WITH CLEANER FEEDERS.

This system has the decided advantage over the pneumatic system with distributor belt that there is no overflow, and all weevils that are in the seed cotton must be deposited within the feeders.

A great deal of ingenuity has been used in the construction of the feeders considered under this head, but the principles upon which they operate are very similar. In Texas 33½ per cent and in Louisiana 19½ per cent of the ginneries are provided with these feeders.

Use of the cleaner feeder.—In these machines the seed cotton is drawn through tubing to the pneumatic elevator resting directly upon the

feeder itself, which in turn rests upon the top of the gin stand. The seed cotton is separated from the air current by the screen, where it becomes dead and drops into the closed hopper, the mass passing gradually between fluted rollers, from which it is received by a picker roller making about 170 revolutions per minute. As each lock of cotton reaches the picker roller it is revolved many times, being beaten against a curved screen which has generally a clear opening of one-third of an inch. It is then discharged directly into the breast of the gin stand. The screen and all other parts mentioned are inclosed in tight casting, so that the weevils that may be contained in the seed cotton must either be removed by the action of the picker roller upon the screen or pass with the seed cotton into the gin breast. As is shown on page 14, about 70 per cent of the weevils are separated by the cleaner feeder and about 30 per cent pass into the gin, from which they are thrown out either with the seed or with the motes. In case they pass through the screen with the general trash, they fall directly upon the spiral conveyor, which is continuous from one end of the battery of gins to the other, and are discharged into a spout leading to a trash receptacle, usually placed below. In plain feeder gins, however, as has been noted, this trash is either deposited at the rear of the gin, or is carried to the seed conveyor through which it is blown or carried with the seed to the cars or seed house as may be desired. To summarize, with the pneumatic and cleaner feeder system, there are three avenues for the escape of the boll weevils.

(1) Any specimens that may be drawn by the suction of the fan through the screen above the hopper would have to pass through the fan, which ordinarily makes from 1,500 to 2,000 revolutions per minute. Experiments have proven that they are killed under such circumstances.

(2) Any weevils that remain in the seed cotton as it is driven by the revolving picker roller against the screen at the rear will pass with the seed cotton directly into the breast of the gin and upon the roll of seed cotton which is rotating at all times during the operation of ginning. After reaching this situation, they may pass along with the seed into the seed conveyor, or be thrown out at the mote board, or pass with the lint to the baling machinery, as has been proven by experiments, the details of which have been given in preceding paragraphs.

(3) All weevils separated from the seed cotton by the action of the picker roller in beating against the cleaning screen must be confined to the space below the screen. As there is no other avenue of escape, they must fall upon the spiral conveyor and thus be carried to the outer end of the battery of gins, where, as before stated, with most gins, all the trash is conveyed through a spout leading directly into the seed conveyor.

On account of the weevil's habit of becoming quiet when disturbed, it has been found that there is little danger of individuals that have been fed into the spiral conveyor crawling out before the trash is deposited. This slight danger may be partially obviated by simply covering the conveyor box between the gin stands, so that the only openings into it will be within the screening chamber, and the only outlet will be at the spout leading to the trash receptacle.

Apron cleaner feeder.—This cleaner feeder is designed for use with the basket system of feeding at small ginneries, and also with the distributor-belt system. All the trash, including the weevils, which falls from the revolving apron drops directly upon a spiral conveyor and becomes mixed with the trash removed by the picker roller, beating the seed cotton against the screen beneath it. Both weevils and trash are carried through a pipe at the end of each gin and discharged into the seed conveyor, or a box placed below or upon the floor. In these cleaners the screw conveyor is the length of one gin stand only, and is not connected through a full battery of gins, as is the case with the ordinary cleaner feeder previously described. In order to make it accomplish the same result as in the upright cleaner feeder, it would be necessary to convey the trash through spouts from each separate gin, leading, at the rear of the battery of gins, into a spiral screw conveyor, which would carry the trash to any point desired. This spiral conveyor should discharge between compression rollers, or other devices which could be easily provided, whereby all insects reaching them would be destroyed. This method of destruction will be detailed more fully in the recommendations.

Special cleaner feeders.—In addition to the ordinary and apron cleaner feeders, which have been described, special forms are now manufactured by some companies, and there seems to be considerable activity in improvements in this line of ginning machinery. In some cases these devices combine elevating, cleaning, distributing, hulling, and feeding operations. In the ordinary cleaner feeders the seed cotton is drawn by the suction of the fan and separated from the current of air by a screen. The cotton usually strikes the screen in a more or less compact body, so that comparatively few weevils are driven through this screen. In the improved systems, however, the seed cotton falls directly upon a revolving beater, which drives it against the screen and separates the locks thoroughly. In some cases the cotton is then passed on to another beater, revolving against a similar screen, thus giving it two thorough workings. As the full force of the air passes through these screens, all boll weevils and trash, separated by the combined beating and screening operations, are passed through the fan and thereby destroyed. In one form of feeder, in addition to the two beaters, a picker roller is used, and below that a

huller feeder leading to the gin itself. In connection with the picker roller is a trash flue, and in connection with the huller there is a spiral conveyor for such trash as may have escaped the preceding operations. There can be no doubt that this system is very effective in extracting the weevils from the seed cotton and destroying them. From the present standpoint, however, these machines have the weakness of requiring a belt distributor, because of the fact that the air passes through the screens before the cotton reaches the lower portion of the device. As has been pointed out previously, there is great danger of the weevils escaping and spreading from the surplus which the belt distributor deposits upon the floor of the gin. However, in this case, the very thorough beating and screening through which the cotton has passed undoubtedly largely removes this objection. Although no actual experiments have been performed, it seems certain that practically all of the weevils will be extracted from the seed cotton before it reaches the belt distributor. This system undoubtedly constitutes one of the most thorough cleaning devices for cotton now known.

SEPARATE CLEANERS.

Considerable ingenuity has been exercised in perfecting another class of cleaners, which are separate machines and movable from one point in a ginnery or seed-cotton storage house to another. They are used either in connection with the distributor-belt system at the gin or in the seed-cotton storage house for simply dropping the cotton, or blowing it into stalls or compartments. These machines consist of a picker roller or drum, revolving rapidly against a screen. The débris passing through the screen, which would include many weevils, is drawn through a fan and discharged at various places. These machines have superior merit for cleaning the seed cotton, as they have a very large arc of contact on the screening surface. The speed at which the picker roller is revolved, greatly exceeding that attained in the case of the ordinary feeders, is another decided advantage. The weevils forced through the meshes of this screen are carried through the fan, where experiments have shown that they will be destroyed. It is consequently immaterial whether the trash is blown about the ginyard or into the seed conveyor, as is sometimes done. Unfortunately these excellent machines are not likely to come into general use at the large ginneries for the reason that the seed cotton in passing from the wagon to the bale would have to be rehandled and refed through another suction pipe leading to the gins. The modern cleaner feeders seem to be taking the place of nearly all separate and distinct cleaning devices at the gins. Nevertheless, where seed cotton is taken from the wagons in baskets and fed into the gin stands these machines would be of very decided advantage in eliminating the weevils.

In addition to the various cleaners already described, an entirely distinct machine is now made to be interposed between the cotton supply and the type of pneumatic elevator, the apparatus forming a section in the supply pipe. This machine is, however, also used as a separate and independent cleaner, which may be moved to any place in the ginney. In either case the seed cotton is beaten against a cylindrical screen, being manipulated in such a way as to become practically dead when it falls upon the beaters. The action of the arms of the beaters carries it through the apparatus, giving it constant agitation against the screening surface, which in this cleaner is far greater than that used in any other type. The weevils and other *débris* escaping through the meshes of the screen fall onto a spiral conveyor below, which carries them to any point desired. By passing the discharge through a pair of compressed rollers all weevils would be destroyed, and it would then be immaterial whether the trash were returned to the seed or deposited elsewhere. There seems no doubt that this system would be exceedingly effective in removing and destroying the weevils.

GINS.

There are two principal classes of gins in operation in the United States, known, respectively, as plain and huller gins. In addition to these the roller gin is used principally in sections where Sea Island cotton is produced, and a modification of the saw gin, known as the needle gin, may eventually come into quite extensive use. The avenues of escape of boll weevils from the ordinary saw gins have been described in the preceding pages. In Texas 93 per cent and in Louisiana nearly 42 per cent of all the gins are of this type.

The huller gin.—The huller gin is used particularly in sections where, owing to labor conditions or other causes, the usual care can not be observed in picking, and consequently more or less of the bolls, boll hulls, and other trash are gathered with the cotton. This gin is supposed to yield a better sample from trashy cotton than can be obtained from the plain gin, and seems to be growing in popularity. With the huller gin the seed cotton is fed into the outer breast, where it drops upon a rapidly revolving huller roller which carries it to the saws. The hulls, bolls, etc., are stopped by the projection of the ribs, while the seed cotton is carried by them into the inner breast, where it is ginned. With the case of the huller gin, it seems likely that more weevils will be deposited in the seed than is the case with the plain gin, on account of the fact that they are allowed to drop with the trash into the seed without going through the saws, as is the case in the plain gin. It seems certain, therefore, that the spread of the weevil must be greater with the open feeder and the huller gins than with the open feeder and the plain gins. Nevertheless, there would be no

difficulty in passing the seed cotton through any of the numerous forms of cleaner feeders before it reaches the outer breast of the huller gin, and this would obviate entirely the objection that has just been mentioned. In Texas nearly 7 per cent of the gins are hullers; in Louisiana, 58 per cent.

The roller gin.—In roller gins the seed cotton is thrown into a hopper, whence it is drawn by friction between a grooved or corrugated roller, made of rubber, walrus hide, or some other substance, which presses against a knife. Various methods are used for removing the lint from the roller, as well as for striking the seed from the lint as it is drawn against the knife by the action of the revolving cylinder. It seems likely that in this system some of the weevils would be killed by the doctor knife or by the beater knife used to remove the seed. Nevertheless, a large percentage of them would necessarily pass along with the seed and be conveyed to the seed house. There would be no difficulty in using cleaner feeders to deposit the cotton in a hopper, although special contrivances would be necessary on account of the slow rate at which the cotton is usually ginned by this process. A large portion of the effectiveness of the cleaner feeders is due to the rapidity at which the spiked roller revolves. This would probably result in feeding a heavy surplus into the hopper. It would be an easy matter, however, to arrange a storage for the surplus. The cleaner feeder might be stopped while the surplus is being ginned.

The needle gin.—The needle gin is simply a huller gin with a system of needles set upon a cylinder instead of saws. For the present purposes it is not essentially different from the ordinary huller gin.

HANDLING COTTON AFTER GINNING.

Between the gin and the baling apparatus the lint is handled by two separate systems, the open-condenser system and the lint-flue system.

Open-condenser system.—In the open-condenser system all of the lint from each gin drops directly upon the floor. When a sufficient quantity has accumulated to make a charge it is drawn along on the floor by hand or forks and deposited in the press. During this treatment weevils in the lint, of course, have abundant opportunities for escape. The condenser itself consists of a circular wire or perforated screen drum inclosed in a framework of iron, wood, canvas, or other material, leaving sufficient space to allow the escape of air, dust, etc., from the gin stands. In some cases there is an opening through the floor through which the air escapes, while in a battery of two or more gins the air discharges through double dust and air flues through the roof of the building.

The air-tight lint flue.—In modern ginneries, however, the open-condenser system is being done away with, and the air-tight lint flue

is used in connection with the battery of gins having one large condenser. In this system the weevils have no opportunity to escape from the lint between the gin and the baling apparatus. There follows naturally the suggestion that wherever possible the inclosed lint flues should be used, thus allowing no avenue of escape for the weevils, which must pass through the large condenser and there drop directly into the press.

SUGGESTED IMPROVEMENTS IN DEVICES FOR HANDLING AND GINNING COTTON.

From the preceding accounts it will be seen that many of the devices that have been perfected for cleaning cotton, and thereby improving the sample, are incidentally of great value in eliminating the boll weevil, although none of those tested have been found to be perfect. The following recommendations look toward the modification of these devices in such a way as to increase their efficiency. As the general trend in cotton ginning is toward improving the sample, and as these suggested modifications also accomplish that result, they should be considered carefully by all ginners.

IN THE SEED-COTTON STORAGE HOUSE.

At many of the smaller gins throughout the country the ginhouse and seed-cotton storage houses are combined under one roof. This is the case at $5\frac{1}{4}$ per cent of the ginneries in Texas and at $11\frac{1}{2}$ per cent of those in Louisiana. Many of these buildings have no partitions, the seed only being kept as far from the seed cotton as possible. Although it is understood that in many cases it would not be possible for small ginners to provide separate houses for storing the seed cotton and the cotton seed, nevertheless in some cases it could be done without special inconvenience. It is very evident that where weevils are present the combination of the three houses under one roof is not advisable.

Where the seed cotton is unloaded by hand directly from the wagons into the storage house nothing can be done to destroy the weevils that are brought in with the seed cotton except by the installation of one of the various forms of separate cleaners or droppers. During the latter part of the ginning season a great deal of seed cotton is handled by hand, even at large ginneries, and does not pass through any machinery in the seed-cotton storage house. In such cases it will be necessary to pay particular attention to methods of eliminating the weevil in the ginhouse proper by means of cleaner feeders, cotton cleaners, separators, etc. In all seed-cotton warehouses where elevating pipes are used for receiving the cotton from the wagon and discharging it directly into the room below, or for blowing the seed cotton to different compartments, the most important feature is the

separator itself. This is a perforated wire screen which prevents the seed cotton from passing through the fan. At this separator an effective apparatus for cleaning the seed cotton should be introduced in order to force the weevils that may be removed through a fan. This end might be attained by providing beaters or spiked picker rollers, revolving as closely as possible to the wire separating screen, having the meshes opening one-third of an inch in the clear. The screening surface should be as large as possible. The picker rollers or beaters should run at a high rate of speed. Under these circumstances the suction of the fan would draw out the great majority of the trash which would pass through the fan, thus causing the destruction of the weevils. There is no doubt that the number of weevils could be very materially reduced by such contrivances, which are now manufactured, although it is not possible that all weevils could be eliminated in this way.

Some additional horsepower would be necessary, by reason of the rapid running and extra machinery here recommended. However, it is probable that not more than one additional horsepower would be required. The great majority of the gins undoubtedly have one or more horsepower to spare; still in some cases the lack of a surplus would interfere with the adoption of this recommendation.

IN THE GINHOUSE PROPER.

From the foregoing pages it will be evident that while some of the systems of handling the cotton in the ginhouse proper are more or less effective in eliminating the boll weevil, none of them are absolutely so. The most defective of the mechanical devices are found with the plain feeders, front plain feeders, and huller gins, in connection with the handling of the seed cotton by hand or by distributor belts. In such systems all trash, sand, boll weevils, etc., fall directly to the top of the gin stands or to the floor, or directly into the seed conveyor, whence the weevils may easily reach the seed house.

On the other hand, many of the modern cleaning feeders and cotton cleaners have valuable features as far as the control of the boll weevil is concerned. They confine all of the trash removed in spiral conveyors, where it is under perfect control. The trash from the battery of gins should be carried through a single spiral conveyor, which should be closed between the gins. At the present time the usual method is to scatter this trash broadcast about the gin yard or to pass it into the seed conveyor and thence to the seed house. From this place the weevils that may be contained are frequently transported long distances in seed for planting purposes. It would be a very simple matter to pass all this trash from the battery of gins between two compression rollers made of either wood, iron, or other hard substance, having sufficient

strength to crush all of the weevils that might be contained. After that has been done it would be immaterial whether the *débris* was scattered about the gin yard or sent with the seed to the seed-storage house. The installation of the compression rollers would, therefore, not interfere with the trash taking exactly the same course as it does at the present time. It should be noticed in this connection that the very important point is in having the spiral conveyor continuous with the whole battery of gins and having only one outlet. With some of the cleaner feeders there are separate screw trash conveyors for each stand, situated under the front of the feeder. In such cases it would be necessary to carry the trash from the pipes that are generally provided into one continuous conveyor discharging at one end, where compression rollers could be applied in the manner that has been mentioned.

With the belt-distributor system, it will be necessary to provide a box for the overflow of seed cotton. If the seed cotton is scattered over the floor, the weevils can escape more freely than if dropped into this box. A better method, however, would be to provide, in connection with the separator and vacuum box, a complete cotton cleaner and separator combined. Thus the seed cotton would be practically freed from weevils before it is dropped upon the distributor belt.

With the present huller gins and plain feeders, the boll weevil is kept under less control than with plain gins. All live boll weevils which become loosened from the seed cotton while on the feeder roller necessarily fall down into the seed conveyor and pass out with the seed; with the plain gin, on the other hand, the seed cotton is fed directly into the breast or roller box of the gin, thus coming in contact with the saws immediately. However, this apparent objection to the huller gin could be entirely obviated by the placing of a cleaner feeder above the stand.

With the plain feeders now used the boll weevils are kept much less under control than with the modern cleaning feeders. The seed cotton is dropped upon an endless apron and conveyed against the picker roller, which separates the locks, elevates them, and deposits them directly in the gin breast. Hence all weevils not carried up and deposited directly in the gin breast, or with the huller gins in the outer breast, drop through the full width of this endless apron feeder upon the top of the gin stands and are there scattered in all directions. A practical suggestion concerning the elimination of this difficulty is in the attachment of a movable bottom sheet beneath the apron wherever this would not interfere with the operation of the gin. In some cases there might be difficulty on account of the small space between the revolving apron and the top of the stand. However, wherever a false bottom could be used, all of the trash, including the

weevils, could be made to slide directly into a continuous spiral screw conveyor at the rear of the gin stands. The screw conveyors for the separate gins could easily be made continuous, and the discharge from the full battery of gins could be passed through compression rollers at the end.

From the preceding paragraphs it will be seen that by the installation of cleaning droppers in the seed-cotton storage house and of special cleaners in the ginhouse proper, a great majority of the weevils could be brought under control. Nevertheless, with any of the devices that have been studied, it is apparent that a number of weevils reach the gin itself, and that a considerable percentage of these escape alive, either in the seed or at the mote board. These two avenues of escape illustrate the greatest weakness, as far as the boll weevil is concerned, of the various cleaners which are perfectly constructed for the objects the inventors have had in mind—i. e., simply removing the trash from the cotton. Further inventions may possibly bring about still further perfection in this system of cleaning cotton, but at present manufacturers should devote some attention to the construction of contrivances which will eliminate the weevils from the seed and motes. There would apparently be no insurmountable mechanical difficulties in causing the motes to run to the seed as it falls from the gin. If this could be done and the combined seed and motes could be cleaned by passing along screens in connection with some agitating device, like a picker roller, or over an oscillating perforated bottom, the weevils would be shaken below and there collected by a spiral conveyor and destroyed by means of a pair of compression rollers. It is believed that practically all of the boll weevils in the seed could be destroyed by these means. In case of the use of a screen and picker roller, at least where two fans are used in the elevating system, it would be an easy matter to obtain the desired suction, without involving any additional horsepower whatever. In case of the use of the oscillating bottom, the only additional horsepower necessary would be the very small amount required for causing the agitation and for running the compression rollers. Either device might easily be introduced between the seed chute at the gin and the blower, and would thus not interfere materially with the present course of the seed.

It will be seen that the advantage in conveying the motes to the seed, as suggested in this plan, is that the weevils from both may be extracted at one operation. However, it would be perfectly feasible to collect the motes independently by means of a spiral conveyor and to destroy the weevils contained therein by means of a pair of rollers.

It seems to the writer possible that suction alone might be utilized to separate the weevils from the seed as they are dropped from the saws to the seed chute. At this stage the seeds are thoroughly sepa-

rated, much more so than at any other stage of handling. An average cotton seed weighs about 2 grains, while an average boll weevil weighs only about one-eighth as much, or one-fourth of a grain. Between such extremes it seems feasible to adjust a suction pipe in such a manner as to remove the weevils. Possibly an air blast instead of suction might be used in forcing the weevils toward the motes, with which they might be collected and destroyed. The suction system, however, would have the advantage of furnishing its own device for destroying the weevils, namely, the fan itself, though in that case there would still be the necessity for a separate device for the proper manipulation of the motes. It is believed that the suction or blast could be obtained at the ordinary gin without an independent fan. There will, of course, be difficulties to overcome in constructing a device along the lines suggested, among them that of obtaining an even degree of suction or blast the full width of the seed chute, or for a possibly lessened width, into which the seeds might be brought. Nevertheless, the matter is undoubtedly well worthy of experimental trial.

The same results as those aimed at by the above-described system might be obtained by the use of sand reels, such as are used in oil mills, in connection with the separate gins, or one large reel for the reception of the combined discharge from the battery. Sand reels, however, are rather expensive machines, and require some additional horsepower. Their installation at gins is, therefore, considered much less practicable than the installation of some such device as has been suggested.

CONTROLLING THE BOLL WEEVIL AT OIL MILLS.

Under the present arrangements large numbers of weevils concentrated at the gins in the seed cotton reach the seed house, whence they are conveyed in cars or wagons to the oil mills. There are several avenues of escape at these mills. It has been demonstrated that cotton fields in the vicinity of oil mills which have received seed from infested territories become infested by the weevil sooner than others. The weevils liberated from the seed at the mills frequently get into by-products, particularly hulls, and have been known to be transported to barns when the hulls were carried from the mills for feeding purposes. With the present generally rather ineffective methods for controlling the weevils before the seed reaches the oil mill, control at the mill is scarcely less important than at the gin itself.

When the seed arrives at the mill, it is generally unloaded from the farmers' or ginner's wagons or cars directly into the storage house by hand, although in some cases screw conveyors are used for this purpose. However, after the seed reaches the storage house the methods

of handling it are identical. It is shoveled into large spiral screw conveyors, which in some cases have solid and in other cases perforated-screen bottoms. These conveyors discharge directly into the elevator cups, which in turn deposit the seed in another spiral screw conveyor. This brings the seed to the cleaning apparatus, known as a "boll reel." This is a perforated cylinder, revolving within a closed box. The perforations of the cylinder are larger than the seeds, allowing them to fall through into the closed box below, while retaining larger substances, consisting of bolls, carpels, pieces of cotton stalks, and sweepings, and the general trash from the ginneries. This trash is usually picked over by hand and such portion as may be of value is placed with the seed to pass through the linters. The balance of the trash is deposited in various ways about the building or outside. From the boll reel the seed is conveyed to a sand reel, which consists of a revolving steel cylinder, having perforations smaller than the cotton seed. Up to this point in the handling of seed at the mills, except in those cases where the conveyor has a perforated lining and supplementary screw conveyor for the trash, there are no devices that would have a tendency to eliminate the weevils. However, the sand reel permits boll weevils and other trash—in fact, everything smaller than the seeds—to pass to the chamber below, from which it is usually removed by hand and scattered outside of the buildings. It is very evident, therefore, that this is one point where the weevils are given an opportunity to spread from the oil mills. Nevertheless, excellent opportunity for the destruction of the weevils that have come from the gins is given at this point. This could be accomplished easily by collecting the refuse from the sand reel by means of a spiral conveyer, and passing it between such compression rollers as have been described previously. It is evident that all boll weevils remaining in the seed after it has passed through the sand reel must be carried with the clean seed through air-tight pipes into the seed hopper, which drops them upon the saws of the linter. Should any of the weevils escape the action of the sand reel they would certainly be killed by the close action of the saws of the linter.

Another very important point to be considered is in connection with the carriage of the seed to the oil mill proper. As has been stated, the conveyor runs the full length of the storage house on the outside of the building. In cases where a perforated bottom is provided, the refuse smaller than cotton seed passing through the bottom, which may include many weevils, is simply allowed to fall upon the ground. In other cases, however, this residue is collected by a spiral screw conveyor, to which compression rollers for the destruction of the weevil could be easily attached. If the screw conveyor were provided with an unperforated lining at the bottom, it would carry all weevils

which might not crawl out in transit to the elevator cups and thence to the sand boll reels. Most of the machinery used in the movement of the seed runs at a slow speed, and therefore a considerable percentage of the weevils may escape to the open air.

From the foregoing paragraphs it will be seen that to control the boll weevil at the oil mills would be a very difficult matter. The escape of the pest to the open air and to the hulls is allowed by the present necessary system of hand manipulation and the open conveyors with slowly revolving screws. The only recommendation to be made is that all conveyors should be provided with perforated bottoms, and that the trash passing through should be collected by means of a small spiral conveyor and passed between rollers. It is nevertheless true that this process would destroy only a small percentage of the weevils at the mills. The impossibility of applying any very effective method at the mills emphasizes strongly the necessity of vigorous attempts at the gins.

SUMMARY OF RECOMMENDATIONS.

It should be understood that complete success in keeping the boll weevil out of cotton seed depends upon a combination of the following recommendations for the seed-cotton storage house, in addition to a combination of the recommendations for the ginhouse proper. No one alone could be depended upon. On account of the great seriousness of the boll-weevil problem, the importance of these recommendations deserves the careful attention of every ginner, and farmers should realize that it is decidedly to their advantage to have their cotton ginned where the greatest care is taken with the seed.

I. Where possible, a separate seed-cotton storage house should be provided. In any case, the seed should be stored in a building distinct from the seed-cotton storage house.

II. In the seed-cotton storage house should be installed special cleaners or droppers, which, in addition to removing many weevils, would facilitate ginning and improve the sample.

III. In the ginhouse proper the principal recommendations are that cleaner feeders and cotton cleaners be used more extensively, that the trash therefrom be treated in such a way as to cause the destruction of the weevils, and that a device be perfected for removing and destroying the weevils in the seed and motes.

IV. Wherever the system of handling and ginning cotton is not found to be effective in removing the weevils, and this is the case in practically all the smaller and many of the larger ginneries in Texas and Louisiana, the seed, at least for planting purposes, should always be sacked and fumigated by the ginner in the manner described on

page 9. In regions where the cotton fields are isolated by this means the introduction of the weevils could be delayed considerably.

V. In addition to the care necessary with the seed for planting purposes, the farmer should also take great pains to prevent the introduction of the weevil in seed or hulls for feeding purposes, as well as in refuse from the ginneries, which is sometimes used as a fertilizer. There is no appreciable danger in cake or meal.

VI. At present it does not seem possible to control the boll weevil effectively at the oil mills. The importance the mills at present have in disseminating the weevil, however, could be very materially reduced by the proper care at gins.

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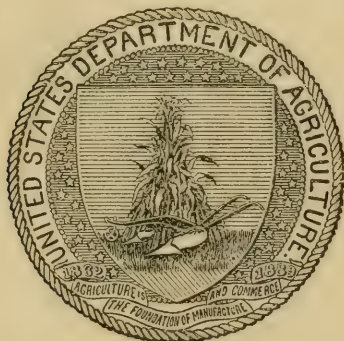
FARMERS' BULLETIN No. 211.

THE USE OF PARIS GREEN IN CONTROLLING THE COTTON BOLL WEEVIL.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., December 5, 1904.

SIR: I herewith transmit a manuscript entitled "The Use of Paris Green in Controlling the Cotton Boll Weevil," prepared by Mr. W. D. Hunter, special agent of this Bureau in charge of the experimental work with the Mexican cotton boll weevil in Texas. On account of a widespread misunderstanding regarding the value of Paris green as a boll weevil remedy, it seems important that this manuscript should be published speedily and in a large edition. I therefore recommend that it be issued as a Farmers' Bulletin.

In the work leading to this bulletin, as well as in the preparation of the manuscript, the author has been materially aided by Dr. W. E. Hinds, principal assistant, as well as by Mr. J. C. Crawford, jr., who has been engaged upon the subject dealt with herein throughout the greater part of the season.

Respectfully,

L. O. HOWARD,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE USE OF PARIS GREEN IN CONTROLLING THE COTTON BOLL WEEVIL.

INTRODUCTION.

During the past season there has been a very extensive use of Paris green in an attempt to control the boll weevil in Texas. This has been due to several mistaken conceptions about the habits of the pest, as well as many misconstructions of the results of applications made in the field by various parties. It has been known for many years that it is possible to destroy a certain number of boll weevils by the use of Paris green, provided applications are made early in the season before any squares are set upon the plants. At this time the weevil feeds on the opening leaflets, and heavy applications of poison destroy a number of them. Many persons have thus killed a certain number of weevils and have concluded that the number found feeding upon the young plants having no squares represents the total number of weevils in the field. As a matter of fact, however, abundant observations have proven that a very great majority of weevils do not come from hibernating quarters until after the plants have begun to put on squares. This is shown in Table VI on a following page. After squares are formed upon the plants the weevils no longer feed upon the leaves, but puncture the squares, and are then beyond the reach of poison. It will be seen from the foregoing statements that early in the season a few weevils may be killed by the use of Paris green, and it is from this fact that the idea has taken hold of many farmers in Texas that in this poison they have a specific against the pest.

On account of the very great attention which has been called to the proposed method of controlling the boll weevil by means of Paris green the Department of Agriculture has devoted special attention to the matter. Experiments have been performed at different points in Texas upon the experimental farms of the Bureau of Entomology, in which care was taken to eliminate all disturbing factors and to obtain accurate information regarding the possibility of poisoning the weevil. In addition to this work, agents connected with this Bureau have visited practically all of the fields at which, at one time or another during the season, the owners have supposed that satisfactory results have been procured. The Bureau of Entomology has from time to time during the season warned the planters through the press against

placing too much dependence upon poison, but despite these warnings it is estimated conservatively that at least 25 carloads of Paris green have been used in Texas. The rather complete results of the work that has been conducted by the Bureau of Entomology are presented in the following pages. As a result of all that has been done by the Department, as well as the conclusion from careful examinations of many cotton fields in Texas, the Bureau of Entomology does not recommend the use of Paris green in an attempt to control the boll weevil.

The fact that applications of Paris green will kill a certain per cent of weevils upon treated plants has been known to the agents of the Bureau of Entomology for ten years. Its use through the medium of a spray was suggested as early as 1895 (Circular No. 6, new series) and repeated in 1897 (Circular No. 18, new series; Farmers' Bulletin No. 47) and in 1898 (Circular No. 33, new series). It was, however, recommended then only as a means of killing off some of the hibernated weevils before squares appeared on the cotton.

Through the repeated experiences of several seasons it had been found that spraying cotton with a solution of Paris green had no positive value in controlling the boll weevil throughout the season, and this conclusion has been generally accepted as well established. Therefore the work of the agents of the Bureau of Entomology with Paris green during the season of 1904 has been confined mainly to the application of the poison as a dry powder. Many claims have been made for the superiority of this method of using the poison and for its efficacy, when so used, as a remedy for the Mexican cotton boll weevil. Early in the spring of 1904 a comprehensive series of tests was begun upon areas sufficiently small to allow every plant to be thoroughly prepared, treated, and examined, so that as far as is possible in the field every weevil might be accounted for and the exact effect of the poison determined under the varying conditions of the test made.

Upon more extended areas the Bureau of Entomology has this year conducted field tests extending through the season. Checks were kept in these field tests and the results of the poisoning must be judged by a comparison of the crop records of poisoned and check areas, which in all other respects were intended to be under similar conditions and to receive identical treatment. In addition to the field results, determined by agents of this Bureau, the experience of a number of representative, practical planters has been drawn upon.

Whatever results might have been obtained upon small areas, it is evident that only results of actual field practice in various localities and by a number of men could ever demonstrate the advisability of adopting or rejecting the use of dry Paris green in the fight against the weevil.

EXPERIMENTS CONDUCTED BY THE U. S. DEPARTMENT OF AGRICULTURE.

TREATMENT OF SMALL AREAS, WITH CAREFUL EXAMINATIONS.

Conditions covered and methods employed.—In the following series of tests, in order that the number of weevils killed by the poison might be accurately determined, the plants to be treated were carefully examined to find the number of weevils present, disturbing them as little as possible. A tag bearing all necessary information regarding the conditions of the test and of the weevils was placed with each plant. Papers were then spread under the plants, extending considerably beyond the spread of the branches to catch the dead weevils. In spite of this precaution it was soon found that a large proportion of the weevils were missing when later examinations were made. As soon as this fact was observed weevils, so marked with colored pencils as to be positively identifiable, were used, the weevils so marked constituting over 76 per cent of the total number treated. The tests were conducted from April 19 to May 19, giving a range of weather conditions. These were varied by making applications on calm and on windy days, some early in the morning while the plants were wet with dew, others during the middle of the day when the plants were dry, some in the middle of the day but spraying the plants to give dew conditions. Plants with and without squares were treated, and in three of the tests plants used in the test immediately preceding were re-treated, together with the weevils surviving the previous test, thus making conditions as severe as was possible. In part of the tests the poison was applied with a powder gun, and in the remainder was used the method employed for many years in using Paris green against the cotton-leaf worm—of shaking the poison from a sack. An exceedingly heavy rate was used, since the object of the tests was to kill the weevil if it were possible to do so with Paris green.

Spraying.—On April 27 a test was made with a spray consisting of 1 pound of Paris green in 30 gallons of water, 49 plants with 94 weevils on them being thoroughly sprayed. At the last examination, made 72 hours after the application, 78 weevils were found alive, 5 dead, 11 missing; 82.97 per cent surviving. Since this test was not as successful as the tests with dry Paris green nothing further was done with the spray. On this point Prof. E. D. Sanderson (Farm and Ranch, October 8, 1904, p. 16) says:

The dry dust also seems to kill the weevils somewhat more quickly, though in the liquid form the poisons are just as fatal.

Poison blown by a powder gun.—The plants were dry when treated in three of these tests, and the powder was blown in from all directions. Four tests (Table I, Nos. 1, 2, 3, 5) were conducted on seppa

plants without squares. The application of poison, though not measured, was heavy in comparison with those tests in which the poison was sifted from a sack, so that it must have been much heavier than at the rate of 20 pounds per acre (as conservatively stated in Table I). The total number of weevils used was 173. The average time elapsing between the application and the last examination was 48 hours. The number of weevils found alive in the four experiments was 37.49 per cent, dead 39.94 per cent, and missing 22.62 per cent of the total number treated.

TABLE I.—*Results of treatment of cotton plants with dry Paris green.*

Experiment No.	Date Paris green applied.	Number of plants used.	Rate of Paris green per acre in pounds for plants 2 by 4 feet apart.	Number of weevils used.	Number of examinations.	Number of hours elapsed at time of last examination.	Number of weevils found alive.	Number of weevils found dead.	Number of weevils missing.	Per cent of weevils found alive.	Per cent of weevils found dead.	Per cent of weevils missing.
1..	Apr. 19	23	20	26	1	28	6	10	10	23.07	38.46	38.47
2..	Apr. 25	25	20	38	3	62	17	14	7	44.73	36.84	18.63
3..	Apr. 26	45	20	70	2	44	27	34	9	38.57	48.57	12.86
5..	Apr. 28	31	20	39	1	57	17	14	8	43.59	35.89	20.52
6..	May 13	25	20	60	1	20	31	7	22	51.66	11.66	36.68
7..	May 14	25	20	56	1	44	8	11	37	14.28	19.62	66.10
8..	May 16	41	45 ¹⁰ ₁₆	88	1	42	13	13	62	14.77	14.77	70.46
9..	May 17	31	32 ¹⁰ ₁₆	87	1	65	10	31	46	11.49	35.63	52.88
10..	May 18	37	20 ¹⁰ ₁₆	80	1	41	25	36	19	31.25	45.00	23.75
11..	May 19	39	41	95	2	96	21	23	51	21.25	24.21	54.54
12..	May 20	37	73 ¹ ₂	93	2	96	3	39	51	3.12	41.93	54.95
Total...		359		732			178	232	322			
Average			21.25		1.45	54				27.12	32.05	40.89

Poison sifted from a sack.—Five tests (Table I, Nos. 6, 7, 8, 9, 10) were made at Victoria on seppa plants without squares. In tests 8, 9, and 10 the plants were sprayed lightly to give dew conditions. The total number of weevils used was 371, and the average time before making the last examination was 42½ hours. The number of live weevils found was 24.69 per cent and the dead 25.33 per cent of the total number treated, while 49.69 per cent were missing. In three of the tests the exact amount of poison used is recorded and was at the rate of 20, 33, and 45 pounds per acre, respectively, where plants are 2 by 4 feet apart.

Two tests (Table I, Nos. 11, 12) were made upon seppa plants bearing squares. In one test with 95 weevils on 39 plants the last examination, made at the end of 96 hours, showed 21.87 per cent alive, 24.21 per cent dead, and 54.54 per cent missing. Poison was used at the rate of 41 pounds per acre. The second test was made upon 93 weevils on 38 plants. At the last examination at the end of 96 hours 3.12 per cent were alive, 41.93 per cent dead, and 54.95 per cent missing. The rate of poison used was 73 pounds per acre. Wherever the poison was applied so heavily the plants were very badly injured.

These results are abundantly corroborated by Professor Sanderson, who states:

We have made similar experiments with over 500 weevils and were unable to find over 30 per cent dead at the end of 4 or 5 days, while an average of about 9 per cent were found alive at the end of 5 days. The balance of over 60 per cent were missing.

About 10 per cent of the marked weevils recorded as missing upon examinations of treated plants were subsequently found alive upon other plants. A careful series of tests has shown that weevils are incapable of flight after having eaten Paris green. It has also been found that on the average one ten-thousandth of a grain constitutes a fatal dose. It would appear fairly certain, therefore, that nearly all of the missing weevils really escaped alive. If so, then the number of weevils actually found dead approaches very closely to the total number killed, while the number found alive is really less than one-half of those that actually escaped. The period of the emergence of the weevils from hibernating quarters is known to extend over from 6 to 10 weeks, so that at least four applications of poison would be necessary to keep the cotton poisoned thoroughly enough to kill as large a percentage of weevils as was killed in the foregoing tests.

Summary.—Summarizing all of the tests with dry Paris green on small areas gives a total of 732 weevils used. The average time between treatment and last examination was 54 hours. An average of 27.12 per cent of the weevils were found alive, 32.05 per cent dead, and 40.89 per cent missing. The lightest application of poison was 20 pounds per acre, and four applications at this rate could not possibly be profitable, especially since the last applications would be after the cotton had squares, and the number of weevils the poison would kill would be greatly reduced.

No tests were made with very light applications, but the following experiments made on the Government farms and by individuals show the inefficiency of Paris green where the poison was applied at a rate of $1\frac{1}{2}$ to 3 pounds per acre for each application and used throughout the season.

TREATMENT OF LARGE AREAS DURING SEASON OF 1904.

Three experiments were conducted by this Bureau at different places, using Paris green on one plat and making frequent applications throughout the season, keeping an adjoining plat as a check, both plats being planted at the same time with the same kind of seed and both cultivated exactly alike.

Field experiments at San Antonio.—At San Antonio a field of 1.70 acres planted with King cotton was chosen. This field was comparatively isolated, there being no nearby cotton except on one side and this was separated from the test fields by a dense strip of sorghum 124

feet wide. One-half was kept as a check and, beginning when the first squares were formed, Paris green was applied by means of the sack-shaking method on the following dates:

	Pounds per acre.
June 10.....	1
June 16.....	1½
June 24.....	1½
July 5.....	1½
July 15.....	1½
August 1.....	1½

From July 13 to August 3 examinations were made to ascertain the relative number of squares infested on the poisoned plat and its check. Blooming ceased before the first examination was made, and at practically the same time on both plats, so the table does not show the relative infestation while blooming was in progress, but it does show most conclusively that the poison did not kill enough weevils to allow the treated plat to keep on blooming and producing bolls after the untreated check had stopped blooming.

TABLE II.—*Examinations of Paris-green experiment, San Antonio, Tex.*

Plat.	Date examined.	Number of squares examined.	Number infested.	Per cent infested.	Number of small bolls examined.	Number of small bolls infested.	Per cent of small bolls infested.
Paris green.....	July 13	78	70	89.74	3	3	100.0
Check.....	do	93	87	93.54	0	0	0
Paris green.....	July 27	91	76	83.51	5	2	40.0
Check.....	do	90	78	86.66	8	3	37.5
Paris green.....	Aug. 3	88	85	96.59	10	3	30.0
Check.....	do	69	61	88.40	10	4	40.0

An average of all examinations on Paris-green plat shows 89.94 per cent infested and on the check 89.53 per cent. The fact that the percentages are almost identical shows that the poison had practically no effect.

The poisoned area yielded 190 pounds and the check 93 pounds of seed cotton, an increase on the poisoned plat of 97 pounds, which would be a gain of 113 pounds per acre. The cost of poisoning was about \$1.80 per acre, so that, making no allowances for the circumstances noted in the following paragraph, the net gain was only about \$2.15 per acre, reckoning seed cotton at 3½ cents per pound.

Running diagonally across the poisoned plat was an old road, the presence of which was not known when the experiment was planned. This road touches only one corner of the check plat. Along the location of this old road the cotton grew very rankly and produced much more abundantly than did the adjacent portions of the field. Making an allowance for the increased production on the Paris-green treated

plat due to this old road, it will be seen that the real increase, if any, due to the treatment would not have paid for its application. It did not lengthen the period of blooming, increase the number of blooms, or produce any marked increase in the yield.

Field experiments at Mexia.—A field of $1\frac{1}{2}$ acres in the form of a right-angled triangle was divided into a 1-acre plat for poisoning and a one-half acre plat for check. On one side of the field, but separated from it by a gully 20 yards wide, was another cotton field; the other two sides were adjacent to a peach orchard and to farm buildings. Beginning immediately after the first chopping an application of Paris green of 1 pound per acre was made from a sack on each of the following dates: May 16, 24, June 8, 29, July 8, August 4. From July 30 to September 13 five examinations were made to determine the relative number of squares infested on the poisoned plat and on the check.

TABLE III.—*Examinations of Paris-green experiment, Mexia, Tex.*

Plat.	Date examined.	Number of squares examined.	Number infested.	Per cent infested.	Number of small bolls examined.	Number of small bolls infested.	Per cent of small bolls infested.
Paris green	July 30	58	50	86.2	31	25	80.0
Check	do ..	60	52	86.6	20	16	80.0
Paris green	Aug. 9	28	24	85.7	62	52	83.8
Check	do ..	22	19	86.4	43	37	86.3
Paris green	Aug. 16	10	10	100.0	40	39	97.5
Check	do ..	12	12	100.0	50	50	100.0
Paris green	Aug. 29	80	72	90.0	18	18	100.0
Check	do ..	77	74	96.1	42	42	100.0
Paris green	Sept. 13	134	125	93.1	12	11	91.6
Check	do ..	102	94	92.1	16	16	100.0

An average of these five examinations shows that on the Paris-green plat 91 per cent and on the check 92.2 per cent of the squares were infested. The fact that the percentages are almost identical shows that the poison had no effect, and this conclusion is borne out by the yield. The poisoned plats produced 270 pounds of seed cotton, while the check, which is only one-half the size of the poisoned area, gave 200 pounds, or an excess of 50 per cent over the poisoned area.

Field experiments at Calvert.—An isolated 5-acre field was divided so that one-half of it served as a check. The entire field was planted during the third week in March, but growth was delayed by unfavorable weather conditions. Beginning immediately after the first chopping, May 26, applications of 1 pound of poison per acre were made every seven days. Fifteen applications were made in all, the last being on August 31. The cost of the poison used was \$6.20 and the labor \$10.80, making a total of \$17. The method of applying the poison

was the usual method of sifting from a sack. Early in the season three examinations were made of lots of ten plants in each plat to determine the number of weevils.

TABLE IV.—*Number of adult weevils found, Paris-green experiment, Calvert, Tex.*

Plat.	Date.	Number of weevils.
Paris green	July 21	0
Check.....	do	0
Paris green	Aug. 4	0
Check.....	do	0
Paris green	Aug. 15	16
Check.....	do	18

Later two examinations were made to determine the relative numbers of infested and uninfested squares and bolls.

TABLE V.—*Infestation of squares and bolls, Paris-green experiment, Calvert, Tex.*

Plat.	Date examined.	Number of squares examined.	Number infested.	Per cent infested.	Number of small bolls examined.	Number of small bolls infested.	Per cent of small bolls infested.
Paris green	Aug. 23	128	124	97.7	80	3	2.3
Check	do	133	119	90.0	95	5	3.8
Paris green.....	Sept. 9	141	131	92.9	30	30	100.0
Check	do	102	97	95.0	34	33	97.0

These examinations show only a very slight difference in percentages of infestation, which was in all cases so great as to prevent flowering. It will be seen that the poisoning had no appreciable effect.

The poisoned plat yielded 1,217 pounds of seed cotton and the check 1,070 pounds, which is an excess of 147 pounds for the poisoned plat. Reckoning seed cotton at $3\frac{1}{2}$ cents per pound there was a gain of \$5.15. The total cost of poison and labor was \$17, making a loss of \$11.85, or \$4.74 per acre.

EXPERIMENTS CONDUCTED BY VARIOUS PLANTERS.

Mr. J. C. Houston, Floresville.

The 2-acre field poisoned was isolated. There was a road on one side, pastures on two sides, and a house on the fourth side. The cotton was seppa and received five applications of poison at the rate of $1\frac{1}{2}$ pounds per acre, in addition to which one-half of the field had a further application of 3 pounds. All applications were made before June 1 and by the sack-shaking method.

On June 9 an examination of this field showed that 30 per cent of the squares were infested, and on July 2, when 71 per cent were

infested, the field had stopped blooming. Weevils were so numerous at that time that there was no chance of further formation of bolls. As the yield was somewhat less than 250 pounds of seed cotton per acre, it can not be considered that the use of poison was successful.

Mr. W. Withers, Lockhart.

Plat 1.—1 acre, King. Mar. 22.	Plat 6.—27 acres, Mebane. Mar. 17.
Plat 2.—4 acres, King. Apr. 12.	
Plat 3.—13 acres, Mebane. Apr. 12.	
Plat 4.—15 acres, King. Apr. 12.	
	Plat 5.—5 acres, Mebane. Mar. 17.

The above sketch, with the exception of plat 6, represents the fields which were poisoned once by means of a powder gun at the rate of 2 pounds per acre. With the following exceptions, the fields were all cultivated exactly alike, each being plowed nine times. Plat 1 was broken four times, as follows: In July, in August, and in September, 1903, and in February, 1904. The other fields were broken only in the spring, when plat 3 was double bedded, while plats 5 and 6 were single bedded.

The yield upon plat 6, which was not poisoned, as well as upon the remainder of the plantation, averaged about one-half bale per acre. On plat 5 the yield was about the same; plat 3 gave three-fifths bale per acre; plats 2 and 4 about 340 pounds of lint per acre, while plat 1 produced over two bales. In other words, plat 5 was no better than cotton which was not poisoned, while plat 3, which was double bedded, was better than either plat 5 or cotton which was not poisoned. This difference in yield can be attributed only to the better preparation of the land before planting, for plat 3 was planted nearly a month later than plat 5. The value of thorough preparation of the land before planting is more strikingly shown in the contrast between plats 1 and 4. Plat 1, while only 1 acre in area, was thoroughly broken four times before planting and produced over two bales, while plat 4 with one spring breaking produced less than four-fifths bale per acre.

Mr. Withers also poisoned a 5-acre field six times at the rate of 2 pounds per acre for each application and this field did not produce as

much as did fields which were not poisoned. When these facts are considered it becomes evident that the increase in production in the plats mentioned above was largely the result of increased cultivation rather than the result of poisoning.

Mr. J. Zachary, Lockhart.

At one end of a 10-acre field on the plantation of Mr. Zachary about 30 rows were poisoned from six to eight times by Capt. B. W. Marston; the rest of the field was used as a check. Otherwise conditions were the same in the two plats, each having been planted at the same time and with the same variety of seed. Mr. Zachary states that the check produced more per acre than did that part of the field which was poisoned.

In addition to the 30 rows treated by Captain Marston, Mr. Zachary himself poisoned some cotton, treating it about five times. In this experiment also the nonpoisoned cotton was the better.

Mr. J. T. Shanks, Cuero.

The area poisoned was in the open field with a road on one side and cotton on the other three sides. The fields were planted early in March and were thoroughly worked. Plats of King and native varieties were poisoned by dusting from a sack. The King cotton was poisoned five times at the rate of 1 pound per acre for each of the first three applications and $2\frac{1}{2}$ pounds each for the last two. The native cotton adjoining the King was poisoned four times at the same rates. Near by this plat was native cotton poisoned three times and also some poisoned only twice.

The King cotton produced about one-half bale per acre. The native cotton poisoned four times produced about the same. The other cotton poisoned did not show any difference in yield between that poisoned twice and that poisoned three times, nor any material difference over cotton not poisoned. As there was no check for the King cotton, there is no way of telling whether that variety was benefited by the poisoning. But in the native cotton the fact that cotton poisoned twice or three times did not show an increase in production over cotton not poisoned at all indicates that the greater production by the part poisoned four times may have been due to some other agency than Paris green. According to a recent statement made by Mr. Shanks in the presence of the writer (November 26, 1904), there were two neighboring fields planted upon exactly the same kind of soil which were not poisoned, but which produced as much cotton per acre as did the field in question. There is, therefore, no doubt that this experiment is absolutely inconclusive.

Mr. W. D. Keyser, Marlin.

These fields were visited on September 9 by Mr. G. H. Harris, who reports as follows: Mr. Keyser had twice poisoned a 24-acre block at the rate of $2\frac{1}{2}$ pounds per acre. The adjoining nonpoisoned field appeared to be equally well fruited, but no blooms were seen in either field.

Another 20-acre field was poisoned twice with a half pound per acre at each application. The adjoining field, though not poisoned, appeared to be equally as good.

In another field one part was poisoned twice with 1 pound per acre, one part four times with $1\frac{1}{2}$ pounds per acre, and the balance was not poisoned. No difference was found in the number of bolls or blooms on the plants counted, and as many weevils were found in one part as in another.

The fact that Mr. Keyser's crop is better this year than heretofore is due to the fact that this year he has planted improved seed—King and Indian Territory mainly. Other near-by fields were seen which, while not poisoned, were as good or even better than Mr. Keyser's poisoned fields.

Rev. J. M. Purcell, Lockhart.

All of the cotton used in the following experiments was planted in rows 40 inches apart, with plants 2 feet apart in the drill. All fields were plowed four times. All were poisoned four times by means of a powder gun at intervals of ten days. The first application was made on July 18 and the rates of application were 2, 2, 2, and 6 pounds per acre. Each of the four experiments had an adequate check. In two of the tests the poison was applied early in the morning while the plants were still wet with dew, and in the other two the poison was put on after the plants had become entirely dry, the theory being that the poison would enter the involucres of the bolls and squares.

The first field, about $2\frac{1}{2}$ acres in area, was located on a hillside and the part poisoned was a triangular piece of one-half acre. This field was planted early in March with native seed, but replanted after being cut down by hail on May 16. To this field the poison was applied while the plants were dry and the yield was nearly 700 pounds of seed cotton, while the check produced almost nothing.

All of the following fields were entirely cut down by the hail on May 16 and were replanted with common native seed about May 30. The cotton was about waist high when first poisoned.

The second field was located on bottom land with woods and creek on two sides, the land sloping upward and away from the creek to the northward and at this end of the field was the check; the southern end of the field was 1 acre in area and was poisoned when the plants

were dry; lying between this and the check was one-half acre separated from these two plats by strips 30 feet wide, and to this area the poison was applied while the dew was on the plants.

The yield of the 1-acre field, poisoned when the plants were dry, was nearly 1,000 pounds of seed cotton. The field poisoned while wet with dew gave about enough to pay for the cost of the poison, while the check produced almost nothing.

The other field, which was poisoned while wet with dew, was also on bottom land with woods and a creek on one side and corn on one side, the nearest cotton being about 100 yards away. The area of this field was about 14 acres and the part poisoned was in the center of the field. The result of this test is identical with the other test in which the cotton was poisoned while wet; that is, the yield will about pay for the cost of the poison.

These results show failure in both tests where the usual method was followed of applying the poison when the dew was on the plants, while both those tests in which the poison was applied when the plants were dry were apparently successful. These are the only instances of even apparently successful use of Paris green known to the writer. When considered in connection with the great number of unquestionable failures, it would seem that some other agency than the poison may have been responsible for this apparent success. Mr. Purcell is not inclined to accept the results as a conclusive demonstration of success in poisoning while the plants are dry and says that the experiments must be repeated next season to prove an actual demonstration.

Planters at Hearne.

A number of large planters living around Hearne poisoned all of their cotton two or three times this season for the leaf worm, but they are unanimous in stating that it is ineffective against the boll weevil. Among those who have used Paris green extensively may be mentioned Mr. C. G. Woods, who poisoned a 20-acre field five times, using $2\frac{1}{2}$ pounds per acre at each treatment, the first application being made when the cotton began to square. The yield of this field was no better than that of fields which were not poisoned. Mr. Woods also poisoned about 300 acres twice during May and June at about the same rate as above, but says that the yield is no better than that of other cotton which was not poisoned.

Col. R. J. White poisoned over 2,000 acres three times for leaf worm, beginning about July 20, and using $1\frac{1}{2}$ pounds per acre at each application. He says that the poisoned cotton has yielded no better than cotton on similar lands which was not poisoned, and that Paris green is of no use in fighting the weevil. The tendency in this locality is to drop poison entirely, for in the presence of the boll weevil the

leaf worm is considered a friend instead of an enemy, and planters who have several thousand pounds of poison on hand at the present time declare that they will not use another pound of it.

SOME REASONS FOR APPARENT EFFECTIVENESS OF PARIS GREEN.

There are several circumstances which have led some users of Paris green during the growing season to conclude that the applications of poison were effectual, but upon closer examination it may be seen that these appearances depend upon other causes than the application of poison. The active life of the hibernated weevil may extend over from 60 to 80 days, so that during the latter part of May and during June a majority of the weevils which lived through the winter, having by that time deposited their eggs, are dying naturally, and these dead weevils being found in the poisoned fields have given the impression that they were killed by the Paris green. A good illustration of the dying of hibernated weevils was seen in a field of Mr. José Cassiano, San Antonio, Tex., who found many dead weevils in a field early in June, and concluded that ants were killing them. An examination showed that the ants were simply carrying off weevils which had died. Others have reported that after poisoning their fields they have found as many dead weevils in the part not poisoned as in that to which poison was applied. At Runge the business men made the following test before deciding whether they should recommend the use of Paris green: Two plants were placed under screens, one poisoned and one not poisoned, and upon each of these plants was placed the same number of weevils. They found that as many weevils died on the plant which was not poisoned as upon that which was poisoned.

Another apparent reason results from the condition called "spotted crop," which has been very common this year. One field where there is no apparent reason for such condition will show a good crop on some parts of the field while other parts will have nothing, and this unevenness exists without regard to the poisoning of the field. If it should happen that the poisoned part should produce the best crop, the owner would naturally conclude that the poison was the effective cause. As happened in several instances, however, the part of the field naturally inclined to produce a poorer crop was poisoned and produced very little, while the nonpoisoned portion of the field yielded a much better crop.

In many cases where poison was applied the farmer provided no adequate check upon the poisoned area. In such cases there is no way of telling how much or how little effect the poison had. The owner

might conclude that the field to which he applied poison yielded much better than it would have done if not poisoned, whereas his neighbors who did not use poison could frequently show as good or even better crops than the man using poison.

It is an unquestionable fact that many persons are very responsive to suggestions. A patient having taken medicine expects to improve, and may recover if the remedy applied were not injurious, even if it were not helpful. In the same way a planter, having applied what appeals to his mind as a remedy for the boll weevil, will expect beneficial effects to follow the application. He will look then for, and probably find, dead weevils, many of which died a natural death. He will examine the plants with care, and as the hibernated weevils die off in numbers, while the development of their progeny is slow and gradual, he will notice what is frequently, if not generally, the real condition, that from the middle to the last of June, or, more exactly, from four to six weeks after the first squares become about half grown, fewer adult weevils are to be found in the field than could be found when squaring began. Then again the rapidly increasing number of squares so greatly decreases the proportional number of weevils that it seems that weevils have almost entirely disappeared. When the cotton opens the user of poison is likely to think that he can see a marked difference in favor of the treated cotton. As an example of this may be mentioned two fields in Cuero, one of which was poisoned twice and one three times. When the cotton was opening the owner stated that there was a distinct gradation between the cotton not poisoned, that poisoned twice, and that poisoned three times, but upon picking he found that there was practically no difference in the yield under the three conditions. Other instances of this tendency could be given.

The difficulty of estimating the quantity of cotton a field will yield often leads to wild predictions on this point, whereas picking weights show that there was little or no difference. Of the planters whose experiments have been reported in this bulletin, it will be noticed that many who used poison on their plantations invariably applied it to the improved varieties, if they had planted any such varieties. Messrs. Zachary, Purcell, and the planters at Hearne did not plant King or Territory seed, while the others did. Mr. Houston poisoned a field of seppa cotton situated in town. The application of the poison to improved varieties was in a large measure responsible for the apparent success of the poison treatment. As a matter of fact these varieties invariably yield more than native cottons without any special attention whatever.

Another important error has been due to the fact that early applications of Paris green have prevented defoliation by the caterpillars. Consequently, many poisoned areas have had the appearance of yielding

much better than untreated ones, though this appearance is altogether deceptive, and due to the uninterrupted growth of the plants treated.

However, the greatest source of error has been the one mentioned in the introduction, namely, that the destruction of the few weevils found upon the plants before any squares have been set represents but a small fraction of the total number that will later emerge from hibernating quarters to damage the crop. That the number found early in the season is but a small portion of the whole, is shown by the following table:

TABLE VI.—*Gradual emergence of weevils from hibernation at Victoria, Tex.*

Date collected.	Number of weevils taken.	Per cent of total number taken.	Date collected.	Number of weevils taken.	Per cent of total number taken.
1904.			1904.		
Mar. 18	19	2.72	Apr. 26	15	2.14
Mar. 25	20	2.86	May 1	24	3.43
Mar. 31	76	10.88	May 11	152	21.77
Apr. 5	35	5.01	May 17	95	13.60
Apr. 12	60	8.59	May 19	60	8.59
Apr. 16	40	5.73	May 21-24	102	14.61

The above table records 12 examinations, in which 698 weevils were taken. Of this number 37.96 were collected before May 1 and 62.04 after that date. The plants began to put on squares numerously about May 1. These hibernated weevils were collected from seppa plants scattered over $4\frac{1}{2}$ acres of ground planted with cotton in 1903. The block examined was surrounded on three sides by cotton ground and on the fourth side bounded by a road. All seppa cotton on the surrounding area was kept down, so that there was no chance of any breeding, and no other fields were near enough for weevils to have come from them. All the plants were examined and the weevils collected to prevent the recounting of weevils. In Table VI the total number of weevils collected is called 100 per cent, although the large number taken at the last examination shows that even then many weevils were still coming out of hibernation.

An impression equally as mistaken as that all hibernated weevils emerge at the same time is that the boll weevil moves from the squares at night to feed upon the dewdrops upon the leaves. Abundant observation has shown that the insect moves very little at night, being almost entirely diurnal.

CONCLUSION.

Repeated tests have shown that about 30 per cent of the weevils on the plants may be killed by a heavy application of poison when the plants are small and without squares. But since the gradual emergence of weevils from hibernation extends over a period of from six to ten

weeks, so that it continues long after squares have formed, the killing of 30 per cent at the time squares begin to form means really but a very small percentage of the total number of hibernated weevils. Continuous use of poison throughout the season on the Government farms has not shown any gain from the use of poison. The tests made by individuals have, as a whole, failed, there being only one instance of apparent success in contrast to the great number of admitted failures. Even where apparently successful the results were mainly due to the yield from improved seed being contrasted with that from native seed. The greatest apparent success was in the field of Mr. W. Withers, Lockhart, Tex., where the land was repeatedly broken prior to planting, and King seed was planted early, followed by thorough cultivation. This plat yielded immensely superior results over other plats in which the same variety of seed was planted later on land not so thoroughly prepared. *No instance could show more strikingly the failure in the use of Paris green, and at the same time emphasize more conclusively the efficiency of the cultural method.*

SUMMARY.

From the rather extensive observations and experiments noted on the preceding pages the Bureau of Entomology concludes that the use of Paris green in controlling the boll weevil is absolutely futile. This conclusion is based upon the following determined facts:

I. Persistent use of Paris green from the time of chopping until picking (in some cases as many as 15 applications) has failed to materially reduce the numbers of the weevils or to increase the yield.

II. Careful examination of very many experiments with the poison made by planters in Texas has failed to reveal conclusive instances of its successful use.

III. Reasons for the impossibility of poisoning weevils successfully are to be found in the facts that only a very small percentage emerge from hibernation before the squares are set upon the plants, that they do not drink the dew on the leaves at night, and that as soon as squares are set all feeding is done within the shelter of the bracts (shuck) beyond the reach of any poison that might be applied.

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The following is a list of the Farmers' Bulletins available for distribution, showing the number and title of each. Copies will be sent free to any address in the United States on application to a Senator, Representative, or Delegate in Congress, or to the Secretary of Agriculture, Washington, D. C. Numbers omitted have been discontinued, being superseded by later bulletins.

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U. S. DEPARTMENT OF AGRICULTURE.

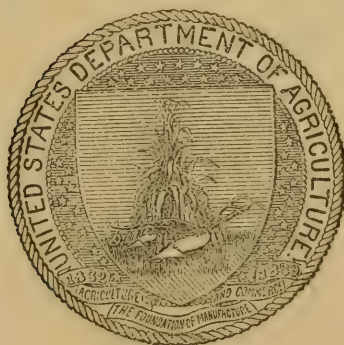
FARMERS' BULLETIN No. 212.

THE COTTON BOLLWORM:

SOME OBSERVATIONS AND RESULTS
OF FIELD EXPERIMENTS IN 1904.

By

A. L. QUAINANCE AND F. C. BISHOPP,
Of the Bureau of Entomology.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.

1905.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., January 14, 1905.

SIR: I have the honor to transmit herewith the manuscript of an account of The Cotton Bollworm, based upon investigations conducted during the year 1904, prepared by A. L. Quaintance and F. C. Bishopp of this Bureau, and to recommend the immediate publication of the same as a Farmers' Bulletin. The investigations are in continuation of those reported for the year 1903 and published as Farmers' Bulletin No. 191, which this bulletin is designed to supersede.

Very respectfully,

L. O. HOWARD,
Entomologist.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE COTTON BOLLWORM.^a

INTRODUCTION.

The cotton bollworm became known as an enemy of cotton early in the history of the cultivation of this crop in the United States. As the industry has grown, the losses from this insect have assumed greater proportions, especially in the absence of the employment of any remedial measures, and more particularly in the Southwestern States of the cotton belt, where farming conditions and practices have been least calculated to interfere with its successful development.

From long familiarity, planters have become more or less accustomed to its ravages, and the disposition has been to regard these as necessarily incident to cotton culture. The fact that serious injury has been of irregular occurrence has contributed to the disposition to neglect the adoption of remedial measures long known to be of value. Probably the most difficult feature of the whole question of lessening the present serious ravages of the bollworm consists in securing the adoption by cotton growers of methods generally admitted to be of value. This difficulty is not peculiar to cotton farmers suffering from bollworm ravages, but finds parallel among the growers of agricultural and horticultural crops generally. Often a pest of long standing will be tolerated, and no effort made to prevent injury from it, whereas the ravages of a recently introduced species become the subject of much complaint; of which facts the cotton boll weevil and the cotton bollworm furnish an excellent illustration. Curiously enough, the crisis in cotton culture in Texas, brought about by the former species, will, it appears, be the means of securing the adoption, in that State at least, of methods of farming best calculated to reduce injury from the cotton bollworm. Certain facts in the life history of the latter species render effective those cultural methods which are of value in avoiding weevil injury. It now appears certain that both of these serious enemies of the cotton plant will be best controlled by identically the same methods of improved farm practice.

^a *Heliothis obsoleta* Fab., formerly known as *H. armiger* Hübner.

SUMMARY OF LIFE HISTORY AND HABITS.

The bollworm has four distinct stages in its development—namely, the egg, larva, pupa, and adult or moth.

The eggs are most easily found on the silks of corn, and may be readily seen with the unaided eye. They are oval in shape, whitish or yellowish in color, and average in diameter about 0.45 to 0.50 mm. The number of eggs deposited by a single moth varies from about 500 to 3,000 with an average of about 1,100. The eggs are laid, beginning usually about twilight, on the several food plants of the larvæ, which are preferably corn, cotton, tomatoes, etc., in about the order named. Eggs on corn are placed almost promiscuously over the plant, but there is shown a preference for silks when these are present. On cotton, eggs are placed more largely on the leaves and squares, but there is a considerable scattering of them over the entire plant. Eggs hatch in from two and one-half to ten days, depending on the season.

In the larval stage, the insect is variously designated as bollworm, bud-worm, corn ear-worm, tomato-fruit worm, etc., depending on the particular plant and part of the plant infested. It is during this stage only that injury is inflicted. Newly hatched bollworms are very small, and are usually overlooked by planters until they are of sufficient size to attract attention by their injury. The bollworm is a voracious feeder, and during the summer may complete its growth in from twelve to fifteen days. During the cool weather of spring and fall the rate of growth is much slower. A full-grown bollworm measures from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in length. Larvæ vary much in color and markings, ranging, in different individuals, from pale greenish to rose-colored, dark brown, and almost black.

When full grown the bollworm leaves its food plant and burrows in the soil to a depth, usually, of from 2 to 5 inches, and, after constructing a cell extending upward nearly to the surface of the soil, enters the pupal stage. This stage, during summer, lasts from ten days to two weeks, and longer in the spring and fall. The insect hibernates in the pupal condition.

The bollworm moth, like its larva, varies much in color, ranging from a dull olive green to a pale yellow. The wings expand about $1\frac{1}{2}$ inches, and the body is about $\frac{7}{8}$ of an inch in length. During the day the moths hide in grass or weeds around the margins of fields or among the foliage of plants infested by the larvæ. Toward dusk they leave their retreats and feed on the nectar of various flowers. In cotton fields their principal food is the nectar secreted on the squares and flowers of the cotton plants. After feeding oviposition begins, or this process may alternate with feeding. Eggs are deposited almost

promiscuously over the plants. This habit of promiscuous oviposition, especially on the cotton plant, renders it possible, during periods of severe bollworm injury, to employ arsenical poisons for the destruction of young larvæ before they are of sufficient size to attack squares and bolls.

The number of generations annually produced by the bollworm in the cotton belt varies from about 4 to 7, depending on the latitude, with an average of about 5. In the latitude of Paris, Tex., there appear to be but 4; at Victoria, Tex., there are apparently 6. The irregularity in time of appearance of moths in the spring and other causes soon produce a confusion of generations, so that these are rarely well marked.

In general, moths issue from hibernating pupæ in the spring, in any locality in the cotton belt, at a time when most of the field corn is from 10 to 20 inches high. By far the larger part of the eggs of these moths is placed on young field corn. A small part is placed on other plants, as garden vegetables, roses, etc. The larvæ resulting from eggs laid on field corn attack the tender central roll of leaves, soon riddling it, and are on this account termed bud-worms. In the latitude of Paris, Tex., moths of the second generation appear as field corn is coming into tassel and silk. These portions of the plant are freely oviposited on, and the second generation of bollworms largely infests the same parts, especially of roasting ears, in which infestation may reach as high as 90 to 100 per cent of the ears. By the time the moths of the next generation are out, field corn has begun to yellow and ripen and is no longer attractive to the moths for oviposition purposes; hence these go to cotton, from which they secure nectar as food and on which most of their eggs are deposited. Cotton is not attacked in force by bollworms until the corn of the locality has begun to ripen, which time will average about the first of August. The third generation of bollworms is the one most destructive to cotton. The fourth generation, also, infests cotton during September, but owing to the attack of parasites, and frequently to unfavorable weather conditions, injury is rarely of serious proportions.

Larvæ of this generation, on completing their growth, enter the soil and transform to pupæ, in which condition the majority remain during the winter. A few may develop moths, and there are thus some bollworms to be found on cotton quite up to frost.

FARM PRACTICE IN RELATION TO BOLLWORM INJURY.

At the present time in the United States injury to cotton from the bollworm assumes its greatest importance in Texas, Louisiana, Mississippi, Indian Territory, Oklahoma, and Arkansas. The rapid increase in cotton acreage during the past ten or twenty years in the

more western part of the cotton belt has contributed largely to the more serious depredations of the bollworm in this territory, as compared with its injuries in the Carolinas, Georgia, and Florida. Those who have followed the development of cotton culture west of the Mississippi during recent years need not be informed how extensive this development has been. Quoting from the Twelfth Census:

Of the entire crop 34.5 per cent was grown west of the Mississippi River in 1879; 38.44 per cent in 1889, and 43.80 per cent in 1899. Of the total increase of 4,099,831 acres in the decade, 1890 to 1900, 3,637,398 acres or 88.7 per cent was contributed by Texas, Indian Territory, and Oklahoma. The increase in Texas was 3,025,824 acres; in Indian Territory, 371,987 acres; in Oklahoma 239,569 acres. This leaves an increase of only 462,433 acres for all the other States, which was nearly reached by the increase of 440,970 acres in Alabama.

The tide of emigration, which about 1850 began to move westward from the more eastern cotton States, peopled this newer country largely with cotton farmers, and cotton has been the crop raised, largely to the exclusion of everything else. Until recently but little attention has been given to diversified farming, corn and cotton being the principal crops grown. As transportation facilities have improved the tendency has been, perhaps, to depend more and more on the North and West for the food supply and to increase the farm acreage in cotton. This extension of the cotton area and neglect of crop diversification has resulted partly from the belief that climate and soil were not adapted to the cultivation of those crops grown successfully farther north, but more largely on account of labor and economic considerations. Landowners have for the most part come to consider cotton as the only crop which may be grown on a large scale with reasonable convenience and safety to themselves, and there has thus been developed a condition of finances which has necessitated the planting of cotton by tenants and small landowners in need of credit, as collateral for the amounts advanced.

Plantations and farms of large size are the rule, and the tenant system, therefore, finds its maximum development in the area under consideration. This fact, in connection with the large areas in cotton, as compared with other crops, and the natural fertility of the soil, which produces a rank succulent plant growth, have been important factors in bringing about the present importance of bollworm ravages.

The cotton crop requires the occupancy of the ground from early in the spring until late in the fall, the growth of the plant being checked only by frost. If the fall be unfavorable, picking may be greatly delayed, often extending through the winter and well into the following spring. Under such circumstances a thorough plowing of the ground in the fall or winter, with its consequent beneficial influence in destroying hibernating pupæ, is not possible, and land

may be planted to cotton several years in succession without a thorough breaking up. By reason of the tenant system of farming, cultivation has, on the whole, been insufficient, and the plant has thus been least able to put on an excess of early fruit, so as to insure a crop in spite of insect attack.

The situation is aggravated by the use of seed which has not been selected for early fruiting or other desirable qualities, often from public ginneries and of absolutely unknown variety.

The principal crops grown, namely cotton and corn, are the two preferred food plants of the bollworm. As a general rule the agricultural practices of the States and Territories mentioned result in conditions theoretically most favorable for the development of this insect. The serious ravages of the bollworm which this territory, and to a less extent other portions of the cotton belt, have suffered, have their explanation in prevalent methods of farm practice. The movement for diversification of crops, now well under way in Texas, and other improvements in farming must gradually bring about that condition of relative immunity from injury enjoyed by the older, more eastern cotton-belt States.

DESTRUCTIVENESS OF THE BOLLWORM.

Bollworm injury varies much from year to year, depending on the relative earliness of the cotton crop, the character of the weather, and

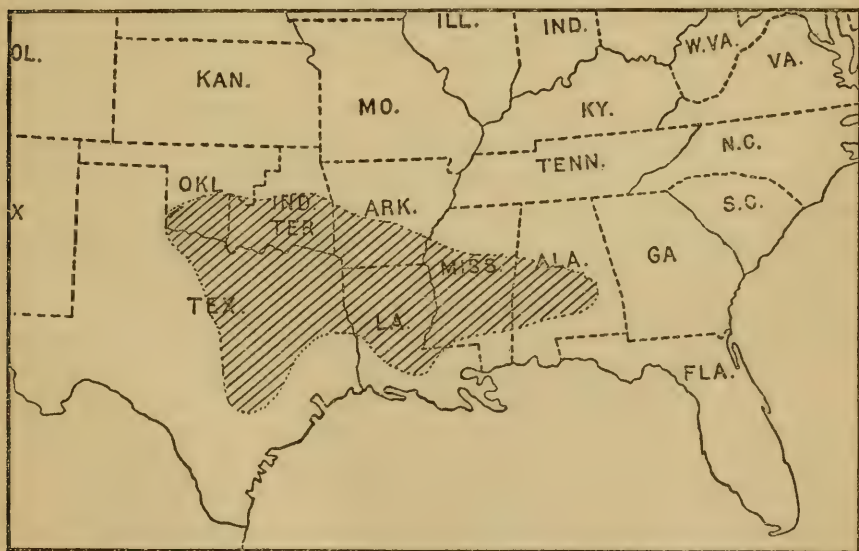


FIG. 1.—Map showing approximately the area of bollworm injury in 1904.

other factors. Not for many years have its depredations been more widespread and serious than during 1903. The heavy and general

rains during the winter of 1902-1903 practically prohibited winter plowing, and from the same cause planting in the spring was everywhere delayed from four to six weeks. Subsequent weather conditions, especially in late July and early August, were such as are held to be most favorable to bollworm development. The general lateness of the cotton crop resulted in there being but little fruit sufficiently matured to be exempt from attack upon the migration of the insects to cotton in early August. The capabilities of the insect for injury under such conditions are very great. In the territory infested by the boll weevil the combined attack of these two species often left but little to be gathered. A yield of 1 bale on from 15 to 25 acres was frequently reported, and in some fields no cotton whatever was gathered.

The following estimates of bollworm injury in 1903 in certain counties in Texas are made up from data from various sources and from personal observation, and are given to indicate the capabilities for injury of this species under such conditions as prevailed during that year:

Estimates of bollworm injury to the cotton crop in certain counties in Texas in 1903.

	Per cent.		Per cent.
Navarro	20 to 25	Lamar.....	40 to 50
Henderson.....	15 to 20	Delta.....	50 to 60
Limestone	20 to 25	Hunt.....	30 to 35
Falls	8 to 10	Hopkins.....	25 to 30
Bell.....	8 to 10	Kaufman	25 to 30
Robertson.....	15 to 20	Van Zandt.....	20 to 25
Fannin.....	50 to 60		

In pleasing contrast were the much less serious ravages of the insect in 1904, when it was only more or less locally that severe injury occurred. The favorable weather of the fall of 1903 and the following winter and spring permitted very general breaking up of land during this period, and many pupæ were undoubtedly thus destroyed. The moths were noticeably much less numerous in young field corn during the spring, and they were subsequently much less abundant, as evidenced by the number of eggs on the silks of early and late corn.

The cotton crop was, on the whole, planted at or before the normal date, and in most fields a fair crop of bolls had so matured by early August as to be exempt from bollworm attack in the presence of an abundance of more tender bolls and squares. While complaint of injury came from a considerable range of territory, it was not, on the whole, of serious extent, except on late cotton on bottom lands.

In the accompanying map (fig. 1) the shaded area marks approximately the territory infested in 1904. The average annual injury to the cotton crop of the South, mostly confined to the western part of the cotton belt, is probably not less than \$11,500,000.

PLAN AND SCOPE OF INVESTIGATION.

The present bollworm investigation has been conducted largely in Texas, in view of the seriousness of the depredations of the pest in that State. The work was begun in the spring of 1903 and has continued to the end of the year 1904. The investigation has been prosecuted both in the laboratory and in the field. During 1903 headquarters were established at Victoria, Tex., where office and other facilities were available in the building occupied by the force engaged in cotton boll weevil investigations. Experiment farms were established at Calvert, Wills Point, and Hetty, Tex., covering in all 140 acres. Only one entomologist was engaged in the work. The more important results of the work of 1903 have been given in Farmers' Bulletin No. 191 of this Department. In 1904, by reason of an increased appropriation, the work was considerably enlarged. Headquarters were established at Paris, Tex., where a laboratory was equipped for the study of all points likely to throw light on methods of control. Four entomologists were continuously engaged in the investigation, and a fifth during the summer and fall months.

In the field, experiments were conducted largely along the lines followed in 1903, as follows: (1) To determine the possibility of making a crop of cotton before the period of greatest bollworm injury, by the early planting of early-maturing varieties of cotton, aided by fertilizers and by thorough cultivation; (2) to determine the value in bollworm control of spraying or dusting cotton with arsenical poisons; (3) to determine the value of corn as a trap crop in protecting cotton from bollworm injury.

In the prosecution of this work it has been necessary for the Department to have control of numerous tracts of land, along with labor and farm equipment. These have been secured by means of contracts with planters whereby the planter has been guaranteed a satisfactory yield of cotton in return for the obligation assumed to carry out the Department's instructions as to the growing and handling of the crop. In the course of the investigation, experiment and demonstration farms have been established as follows:

Experiment farms used in work with the bollworm, 1904.

Location.	Plantation of—	Number of acres.
Paris, Tex.	L. J. Bankhead	40
Ladonia, Tex.	C. T. Jackson	100
Hetty, Tex.	Capt. B. D. Wilson	30
Sulphur Springs, Tex.	Hon. J. T. Hargrove	50
Pittsburg, Tex.	J. F. Harrison	40
Wills Point, Tex.	Capt. A. N. Alford	50
Do	O. L. Johnson	40
Shreveport, La.	Hon. W. L. Foster	40
Mound, La.	Capt. F. L. Maxwell	55
Quinlan, Tex.	Joe Smith	30
Terrell, Tex.	Demonstration farm of E. H. R. Green.	15

In addition to the 490 acres represented above, numerous smaller areas have been utilized in cooperation with planters, increasing the aggregate to about 600 acres.

On these farms tests have been made of every expedient likely to be of value in circumventing bollworm injury. The scheme as to cultural methods has included the comparison of early-maturing varieties of cotton from the more northern States with local varieties, and of early with late planting; a study of the effect of fertilizers in increasing the crop and in hastening maturity; and a comparison of average cultivation with thorough cultivation under all of the above conditions. Such work, as will at once appear, bears directly on the bollworm question in its relation to the production of an early crop.

The accompanying diagram of a 48-acre field will serve to illustrate the method followed in the solution of the several questions involved. The methods of treatment enumerated have thus been brought into comparison under the uniform conditions as to soil, etc., which are necessary in experimental work of this kind.

Experimental cotton plats of the Department of Agriculture at Ladonia, Tex., 1904.

Plat 1. Early planted. Early variety. Thorough cultivation. Fertilized.	Plat 2. Early planted. Early variety. Thorough cultivation. No fertilizer.	Plat 3. Early planted. Native seed. Thorough cultivation. No fertilizer.
Plat 4. Early planted. Early variety. Average cultivation. Fertilized.	Plat 5. Early planted. Early variety. Average cultivation. No fertilizer.	Plat 6. Early planted. Native seed. Average cultivation. No fertilizer.
Plat 7. Late planted. Early variety. Thorough cultivation. Fertilized.	Plat 8. Late planted. Early variety. Thorough cultivation. No fertilizer.	Plat 9. Late planted. Native seed. Thorough cultivation. No fertilizer.
Plat 10. Late planted. Early variety. Average cultivation. Fertilized.	Plat 11. Late planted. Early variety. Average cultivation. No fertilizer.	Plat 12. Late planted. Native seed. Average cultivation. No fertilizer.

Experiments designed more particularly to test the effect of several classes of fertilizers were conducted on the principal types of soil of north Texas, and the plan and results of this work on two of the typ-

ical soils are detailed on a later page. Owing to complications which would result from the presence of the weevil, these experimental farms were as much as possible located in sections comparatively free from this pest in Texas.

One feature of the work has been the comparison of varieties of cotton with especial reference to their earliness, prolificness, and quality of staple. In all, 75 supposed varieties of cotton have been compared during the past year.

In the case of insects attacking staple crops, the margin of profit in their cultivation does not often permit of the employment of remedial measures other than those involving changes or improvements in farm practice. However, the readiness with which cotton may be poisoned with Paris green or other arsenicals, particularly in a dry form, by means of poison blowers or the primitive but effective method of bags suspended from poles, has placed this operation among those which may reasonably be employed. Considerable attention has been given to the matter of testing poisons in bollworm control, both in 1903 and 1904. In all cases the plan has been to measure off, say, 20 acres of uniform cotton, 10 of which would be poisoned and 10 left as a check. The efficacy of the treatment has been measured by the yield from the respective areas.

No rational plan may be formulated for the control of an insect except as based on a thorough knowledge of its life and habits. The importance of life-history studies is therefore evident. The laboratory investigations of the past two years have covered all important features of the biology of the bollworm, confirming many points already known and enlarging our knowledge of the species. The determination of the number of generations was effected by the use of a large breeding cage in which corn and cotton were grown exactly as in the fields. These observations were checked by rearing experiments in the laboratory. The destructive capacity of individual bollworms was determined repeatedly by confining a larva on a cotton plant under a wire cage. The efficacy of poisons was determined in a small way by the same plan. The effect of the destruction of pupal cells, as would be accomplished by plowing, was determined both for low and high temperatures. The length of life cycle and the number of stages has been determined for a large series of individuals covering the entire season. The effect of food on the life and egg laying of the moth, the number of eggs deposited by a single female, conditions which affect their vitality, and many other points have been investigated.

Especial attention has been given to the study of the parasites and predaceous enemies of the bollworm, especially as to their value in keeping this pest in subjection. It has always been a pleasing proposition to import from foreign countries the enemies of a pest and array these against it in the hope of lessening its destructiveness. Early in

the present investigation many foreign entomologists were corresponded with in countries where this species was known to occur in the hope that important enemies of the bollworm might be discovered and imported to this country. No important enemies, however, have been discovered.

SOME RESULTS OF FIELD WORK.

Attention has elsewhere been called to the principal lines of field work. Of first importance is the so-called cultural method, which consists of the employment of all such means as will contribute to the production of an early crop of cotton. This involves especially, (1) the use of seed of early-fruited varieties; (2) early planting in the spring; (3) early and thorough cultivation; (4) the use of fertilizers to hasten and increase the growth of the plant and the development of fruit.

As has been stated, the cotton crops of Texas and adjacent States have, until recently, been largely produced from native-grown seed, often secured from public ginneries and of unknown variety and origin. The accumulated effect of the climate has been to make the crop later and later in maturing, especially in the absence of selection of seed for earliness and other qualities. During years of severe bollworm injury, the insects, upon their migration from ripening corn to cotton in early August, have found but few fields in which the bolls were sufficiently matured and hardened to be unsuitable for food, and practically all of the fruit has been subject to attack. The importance of early planting to avoid bollworm injury has long been recognized by planters, but sufficient attention has not been given to the matter of using improved varieties of seed and to the adoption of improved farm practices. Many observers have noted that relatively less injury was done by the bollworm and other cotton pests, especially the leaf-worm, to early-planted than to late-planted cotton. Thus Riley, as early as 1885, says:

Our knowledge of the natural history of *Aletia* [*Alabama argillacea*] and the yearly occurring experiences with its ravages, teach us that the principal and most effective means of prevention is to hasten the maturity of the plant so that a portion of the crop shall be beyond the reach of harm from the more destructive July and August broods of the worm. * * *

Improving the cotton seed in the direction just mentioned can be accomplished principally by careful selection of early varieties of cotton or possibly by introducing seeds from more northern regions. Early planting is to be strongly urged in this connection, although of course it has its drawbacks in the risks of exceptionally late frosts.

Professor Mally, in discussing certain statistics of the comparative injury by the bollworm to early and late cotton in Texas in 1892, says:

The late cotton, therefore, shows a loss of 50.6 per cent, while the early cotton shows no real loss. This may be taken as an extreme case, but the general principle remains that late cotton receives by far the greater portion of bollworm attack, virtually protecting the cotton fields about it.

The decided preference of bollworms for squares and young bolls, as compared with maturer and more hardened bolls, is shown in the following tables, as is also the comparative injury to early and late-planted cotton:

TABLE I.—*Showing bollworm injury to early-planted and late-planted cotton.*
BOLLWORM INJURY TO EARLY-PLANTED COTTON.

Date of observation.	Locality.	Number of plants examined.	Total injured.						Total uninjured.						Average percent of injury.	Total fruit on plant.	Date of planting.	Variety of seed and kind of soil.	
			Squares.	Very small bolls.	One-fourth-grown bolls.	One-half-grown bolls.	Three-fourths-grown bolls.	Full-grown bolls.	Total.	Squares.	Very small bolls.	One-fourth-grown bolls.	One-half-grown bolls.	Three-fourths-grown bolls.					Full-grown bolls.	Total.
Aug. 9	Ladonia	10	31	56	27	17	4	0	138	65	131	106	53	32	59	446	581	Apr. 1	King. Black-waxy, wooded.
Aug. 11	Ben Franklin	10	13	16	2	4	0	0	25	363	79	88	51	10	23	581	619	Mar. 29	Hall. Black-waxy, wooded.
Aug. 12	Quinlan	10	0	3	3	1	0	0	13	9	65	2	3	15	27	257	272	Apr. 1	King. Post-oak.
Aug. 15	Wills Point	20	15	39	9	0	0	0	63	165	340	141	86	82	397	1,211	1,274	do....	King. Gray, prairie.
Aug. 22	Paris	3	3	17	9	10	1	0	46	11	43	13	16	73	73	183	228	Mar. 30	Big Boll. Black, prairie.
Aug. 31	Almont	10	4	17	3	3	3	0	45	57	135	56	61	153	329	753	798	Mar. 23	King. Red River bottom.
	Total	65	66	165	58	35	8	9	341	610	751	376	273	341	1,053	3,434	3,775		
	Average per cent of injury		9.7	19.5	13.3	11.3	2.3	.8											

INJURY TO LATE-PLANTED COTTON.

Aug. 9	Ladonia	10	75	76	43	20	2	0	216	221	41	73	52	7	1	395	611	35.3	May	King. Black-waxy, wooded.
Aug. 11	Ben Franklin	10	56	55	14	5	1	1	132	221	71	60	32	29	17	430	562	23.5	Apr. 15	Hall. Black-waxy, wooded.
Aug. 12	Quinlan	10	4	29	8	10	1	0	55	88	186	43	74	33	46	492	517	10.0	Apr. 23	Big Boll. Post-oak.
Aug. 15	Wills Point	20	18	37	21	8	6	1	108	290	239	82	70	81	156	969	1,077	10.0	May 2	Rowden. Gray, prairie.
Aug. 22	Paris	5	56	67	13	11	7	3	157	210	53	20	34	50	10	377	534	29.6	May 1	Peterkin. Black, prairie.
Aug. 31	Almont	10	149	84	28	8	1	0	267	602	137	62	38	36	31	996	1,173	23.6	June	Fleming. Red River bottom.
Total		65	358	362	127	62	21	5	935	1,633	747	342	300	256	291	3,559	4,504			
Average per cent of injury			17.9	32.6	29.7	15.9	6.7	1.7												

TABLE II.—*Comparative injury by bollworm to early-planted and late-planted cotton.*

Locality.	Early-planted.			Late-planted.			Per cent in favor of early planting.	Kind of soil.
	Date of planting.	Seed used.	Per cent of injury.	Date of planting.	Seed used.	Per cent of injury.		
Ladonia, Tex.....	Apr. 1	King	23.6	May 2	King	35.3	11.7	Black-waxy, wood- ed.
Ben Franklin, Tex.	Mar. 19	Hall ..	5.6	Apr. 15	Hall	23.5	17.9	Do.
Quinlan, Tex.....	Apr. 1	King	5.5	Apr. 25	Gin.....	10.0	4.5	Post-oak.
Wills Point, Tex.	Mar. 30	do ..	4.9	May 2	Rowden..	10.0	4.1	Gray, prairie.
Paris, Tex.....	do ..	Gin....	19.7	May 1	Gin.....	29.6	9.9	Black, prairie.
Almont, Tex.....	Mar. 23	King	5.6	June 2	Fleming..	23.6	18.0	Red River bottom.
Average of all ob- servations.	.....	.....	9.3	.....	.....	20.7	11.4	

It will be noted that in determining the percentages of injury observations were made on early and late cotton in the same locality and on the same date as shown in Table I, so that the comparisons are quite fair. The average total injury to early cotton was 9.3 per cent as compared with an average total injury of 20.7 per cent to late cotton. This difference is undoubtedly less than would be the case during seasons of more severe injury than occurred in 1904. The decided preference of the bollworm for squares and young bolls is shown in the figures of average percentages of injury given in both tables. Thus the sum of the percentages of injury, as shown in the tables, to squares and bolls one-half grown or less is 149.7, while on bolls from three-fourths to full-grown the percentages of injury only aggregate 11.5.

Many detailed observations have been made during the course of the present investigation bearing out the above statements, and data as to the comparative freedom of early cotton from bollworm injury have been gathered. This fact has been the basis of one of the principal lines of experimental work.

For the completeness of experiments, the presence in injurious numbers of the bollworm has been necessary. Unfortunately, from an experimental point of view, the injuries of this species during 1904 on the several experiment farms were not sufficiently marked to have made the tests as thorough as could be desired. However, the considerable amount of data collected throughout the season on the effects of the several methods of treatment, and the final results, as shown by the weights of cotton produced, are none the less valuable as indicating the relation of such work to the production of an early crop.

WILLS POINT FARM.

The experimental farm at Wills Point, Tex., on the plantation of Mr. O. L. Johnson, was located on a typical gray prairie soil of that sec-

tion. The land had been in cotton for the three preceding years, and its productiveness was considered to be one-third of a bale per acre. The accompanying plan illustrates the arrangement and treatment of the eight 5-acre plats of this experimental farm, together with the yield.

Experimental cotton plats of Department of Agriculture at Wills Point, Tex., 1904.

Plat I. Five acres. Planted March 30, King seed. Fertilized, C. B. G.^a, 400 pounds per acre. Cultivated 8 times. Hoed 4 times. Yield, pounds seed cotton per acre, 986.6.	Plat V. Five acres. Planted April 1, King seed. Unfertilized. Cultivated 8 times. Hoed 4 times. Yield, pounds seed cotton per acre, 765.
Plat II. Five acres. Planted March 30, King seed. Fertilized, R. A. P.^b, 300 pounds per acre. Cultivated 8 times. Hoed 4 times. Yield, pounds seed cotton per acre, 995.6.	Plat VI. Five acres. Planted April 1, King seed. Fertilized, R. A. P.^b, 300 pounds per acre, plus dressing of nitrate of soda, 100 pounds per acre, when plants had 4 to 6 leaves. Cultivated 8 times. Hoed 4 times. Yield, pounds seed cotton per acre, 852.4.
Plat III. Five acres. Planted March 30, King seed. Unfertilized. Cultivated 8 times. Hoed 4 times. Yield, pounds seed cotton per acre, 736.4.	Plat VII. Five acres. Planted April 1, King seed. Fertilized, A. P. & P. M.^c, 300 pounds per acre. Cultivated 8 times. Hoed 4 times. Yield, pounds seed cotton per acre, 831.4.
Plat IV. Five acres. Planted March 30, King seed. Fertilized, A. P. & P. M.^c, 400 pounds per acre. Cultivated 8 times. Hoed 4 times. Yield, pounds seed cotton per acre, 974.	Plat VIII. Five acres. Planted May 2, Rowden seed. Unfertilized. Cultivated 4 times. Hoed 2 times. Yield, pounds seed cotton per acre, 675.4.

^aC. B. G.—A commercial cotton boll guano; analysis—available phosphoric acid, 8 per cent; potash, 2 per cent; nitrogen, 2 per cent.

^bR. A. P.—A commercial acid phosphate; analysis—available phosphoric acid, 14 per cent.

^cA. P. & P. M.—An acid phosphate and potash mixture; analysis—available phosphoric acid, 13.79 per cent; potash, 4.65 per cent.

More detailed figures are given in the following table:

TABLE III.—*Showing treatment of and results from plats on bollworm experiment farm of Department of Agriculture at Wills Point, Tex., 1904.*

Plat number.	Variety of cotton.	Fertilizer and quantity used per acre.	Date of planting.	Number of times cultivated.	Number of times hoed.	Yield per acre in pounds of seed cotton.	Increase per acre in pounds of seed cotton as compared with Plat VIII.	Value of increase per acre at 3,686 cents per pound seed cotton as compared with Plat VIII.	Cost of fertilizer per acre.	Net gain per acre.
I	N. C. King..	C. B. G., 400 pounds.	Mar. 30	8	4	986.6	311.2	\$11.47	\$4.60	\$6.87
II	do	R. A. P., 300 pounds.	do	8	4	995.6	320.2	11.81	2.85	8.96
III	do	Unfertilized.....	do	8	4	736.4	61.0	2.24	.....	2.24
IV	do	A. P. and P. M., 400 pounds.	do	8	4	974.0	298.6	11.01	4.30	6.71
V	do	Unfertilized.....	Apr. 1	8	4	765.0	89.6	3.30	.....	3.30
VI	do	R. A. P., 300 pounds; sodium nitrate, 100 pounds.	do	8	4	852.4	177.0	6.53	5.85	.68
VII	do	A. P. and P. M., 300 pounds.	do	8	4	831.4	156.0	5.75	3.22	2.53
VIII	Rowden	Unfertilized.....	May 2	4	2	675.4	.....	.....	.....	.....

Aside from the yields of cotton, the influence of the several treatments on the fruiting of the plant was determined by actual counts of all the fruit on 20 plants for each plat, on several different dates during the season.

Vigorous, well-branched plants were selected in various parts of each plat. These plants were not marked, and consequently a different set of plants was used each time the counts were made. The fruitage was determined in this way five times during the summer, at intervals of about sixteen days. The first count was made on June 9, square production having just begun; the last on August 15, when the bolls were beginning to open.

The prime object in making these records was to determine the relative earliness of fruit production, (1) with King seed, early planting, fertilizers, and thorough cultivation; (2) with King seed, early planting, no fertilizer, and thorough cultivation, and (3) with Rowden (native) seed, late planting, no fertilizer, and ordinary cultivation. The records made on plants grown under the conditions named in the last group are used as a basis of comparison.

TABLE IV.—*Showing rate of fruiting on respective plats of bollworm experiment farm of Department of Agriculture at Wills Point, Tex., 1904.*

Plat number.	Date of examination.	Average number of squares per plant.	Average number of bolls per plant.				Average increase per plant in number of—				
			One-fourth grown.	One-half to three-fourths grown.	Full-grown.	Open.	Squares as compared with plat 8.	One-fourth grown bolls as compared with plat 8.	One-half to three-fourths grown bolls as compared with plat 8.	Full-grown bolls as compared with plat 8.	Open bolls as compared with plat 8.
I	June 9	6 $\frac{5}{20}$					54 $\frac{3}{20}$				
II	do	5 $\frac{2}{20}$					5 $\frac{3}{20}$				
III	do	2 $\frac{2}{20}$					11 $\frac{3}{20}$				
IV	do	6 $\frac{2}{20}$					54 $\frac{4}{20}$				
V	do	3 $\frac{4}{20}$					3 $\frac{2}{20}$				
VI	do	5 $\frac{2}{20}$					41 $\frac{2}{20}$				
VII	do	6 $\frac{2}{20}$					5 $\frac{2}{20}$				
VIII	do	1 $\frac{2}{20}$									
I	June 23	37 $\frac{15}{20}$	2 $\frac{2}{20}$	2 $\frac{2}{20}$			304 $\frac{2}{20}$	2 $\frac{2}{20}$	2 $\frac{2}{20}$		
II	do	34 $\frac{2}{20}$	2 $\frac{2}{20}$	2 $\frac{2}{20}$			27 $\frac{2}{20}$	2 $\frac{2}{20}$	2 $\frac{2}{20}$		
III	do	20 $\frac{2}{20}$	2 $\frac{2}{20}$				12 $\frac{15}{20}$	2 $\frac{2}{20}$			
IV	do	32 $\frac{2}{20}$	2 $\frac{2}{20}$				25 $\frac{2}{20}$	2 $\frac{2}{20}$			
V	do	20 $\frac{15}{20}$	2 $\frac{2}{20}$				131 $\frac{2}{20}$	2 $\frac{2}{20}$			
VI	do	31 $\frac{2}{20}$	2 $\frac{2}{20}$				24 $\frac{2}{20}$	2 $\frac{2}{20}$			
VII	do	32 $\frac{2}{20}$	2 $\frac{2}{20}$				25 $\frac{2}{20}$	2 $\frac{2}{20}$	1 $\frac{2}{20}$		
VIII	do	7 $\frac{2}{20}$		2 $\frac{2}{20}$				2 $\frac{2}{20}$	2 $\frac{2}{20}$		
I	July 9	100 $\frac{2}{20}$	5 $\frac{4}{20}$	21 $\frac{2}{20}$	2 $\frac{2}{20}$		65 $\frac{2}{20}$	31 $\frac{2}{20}$	21 $\frac{2}{20}$	2 $\frac{2}{20}$	
II	do	73 $\frac{2}{20}$	34 $\frac{2}{20}$	12 $\frac{2}{20}$			38 $\frac{2}{20}$	2 $\frac{2}{20}$	12 $\frac{2}{20}$		
III	do	51 $\frac{2}{20}$	25 $\frac{2}{20}$	2 $\frac{2}{20}$			16	1 $\frac{2}{20}$			
IV	do	89 $\frac{2}{20}$	5 $\frac{2}{20}$	2 $\frac{2}{20}$			54 $\frac{2}{20}$	4 $\frac{2}{20}$	2 $\frac{2}{20}$		
V	do	44 $\frac{2}{20}$	24 $\frac{2}{20}$	2 $\frac{2}{20}$			93 $\frac{2}{20}$	1 $\frac{2}{20}$	3 $\frac{2}{20}$		
VI	do	71	41 $\frac{2}{20}$	2 $\frac{2}{20}$			38 $\frac{2}{20}$	3 $\frac{2}{20}$	2 $\frac{2}{20}$		
VII	do	81 $\frac{2}{20}$	8 $\frac{2}{20}$	1 $\frac{2}{20}$	2 $\frac{2}{20}$		49 $\frac{2}{20}$	7 $\frac{2}{20}$	12 $\frac{2}{20}$	2 $\frac{2}{20}$	
VIII	do	35 $\frac{2}{20}$	1 $\frac{2}{20}$								
I	July 25	64 $\frac{2}{20}$	21 $\frac{2}{20}$	18 $\frac{2}{20}$	91 $\frac{2}{20}$		2 $\frac{2}{20}$	12 $\frac{2}{20}$	15 $\frac{2}{20}$	9 $\frac{2}{20}$	
II	do	67	18 $\frac{2}{20}$	12 $\frac{2}{20}$	9 $\frac{2}{20}$		4 $\frac{2}{20}$	2 $\frac{2}{20}$	9	8 $\frac{2}{20}$	
III	do	76 $\frac{13}{20}$	10 $\frac{2}{20}$	61 $\frac{2}{20}$	5 $\frac{2}{20}$		11 $\frac{2}{20}$	2 $\frac{2}{20}$	31 $\frac{2}{20}$	41 $\frac{2}{20}$	
IV	do	99 $\frac{13}{20}$	17 $\frac{2}{20}$	91 $\frac{2}{20}$	8		37 $\frac{2}{20}$	91 $\frac{2}{20}$	63 $\frac{2}{20}$	71 $\frac{2}{20}$	
V	do	59 $\frac{2}{20}$	12 $\frac{2}{20}$	51 $\frac{2}{20}$	41 $\frac{2}{20}$		23 $\frac{2}{20}$	4 $\frac{2}{20}$	21 $\frac{2}{20}$	4 $\frac{2}{20}$	
VI	do	82 $\frac{2}{20}$	19 $\frac{2}{20}$	91 $\frac{2}{20}$	7 $\frac{2}{20}$		20 $\frac{2}{20}$	11 $\frac{2}{20}$	64 $\frac{2}{20}$	61 $\frac{2}{20}$	
VII	do	701 $\frac{2}{20}$	23 $\frac{2}{20}$	111 $\frac{2}{20}$	8		81 $\frac{2}{20}$	15 $\frac{2}{20}$	81 $\frac{2}{20}$	71 $\frac{2}{20}$	
VIII	do	62 $\frac{2}{20}$	8 $\frac{2}{20}$	3 $\frac{2}{20}$	2 $\frac{2}{20}$						
I	Aug. 15	4 $\frac{2}{20}$	34 $\frac{2}{20}$	8 $\frac{2}{20}$	12 $\frac{2}{20}$	61 $\frac{2}{20}$	-10 $\frac{2}{20}$	-7	1 $\frac{2}{20}$	4 $\frac{2}{20}$	5 $\frac{2}{20}$
II	do	10 $\frac{2}{20}$	101 $\frac{2}{20}$	8 $\frac{2}{20}$	16 $\frac{2}{20}$	3 $\frac{2}{20}$	-3 $\frac{2}{20}$	2 $\frac{2}{20}$	2 $\frac{2}{20}$	8 $\frac{2}{20}$	2 $\frac{2}{20}$
III	do	14 $\frac{2}{20}$	151 $\frac{2}{20}$	8 $\frac{2}{20}$	14 $\frac{2}{20}$	1 $\frac{2}{20}$	2 $\frac{2}{20}$	4 $\frac{2}{20}$	2 $\frac{2}{20}$	61 $\frac{2}{20}$	4 $\frac{2}{20}$
IV	do	5 $\frac{2}{20}$	12 $\frac{2}{20}$	8 $\frac{2}{20}$	16 $\frac{2}{20}$	41 $\frac{2}{20}$	-8 $\frac{2}{20}$	2 $\frac{2}{20}$	1 $\frac{2}{20}$	8 $\frac{2}{20}$	3 $\frac{2}{20}$
V	do	8 $\frac{2}{20}$	9 $\frac{2}{20}$	8 $\frac{2}{20}$	18 $\frac{2}{20}$	1 $\frac{2}{20}$	-5 $\frac{2}{20}$	-1 $\frac{2}{20}$	1 $\frac{2}{20}$	10	3 $\frac{2}{20}$
VI	do	12 $\frac{2}{20}$	101 $\frac{2}{20}$	9 $\frac{2}{20}$	151 $\frac{2}{20}$	31 $\frac{2}{20}$	-2 $\frac{2}{20}$	2 $\frac{2}{20}$	1 $\frac{2}{20}$	71 $\frac{2}{20}$	2 $\frac{2}{20}$
VII	do	21 $\frac{2}{20}$	9 $\frac{2}{20}$	81 $\frac{2}{20}$	13 $\frac{2}{20}$	31 $\frac{2}{20}$	-11 $\frac{2}{20}$	-1 $\frac{2}{20}$	1 $\frac{2}{20}$	5 $\frac{2}{20}$	2 $\frac{2}{20}$
VIII	do	14 $\frac{2}{20}$	101 $\frac{2}{20}$	71 $\frac{2}{20}$	8 $\frac{2}{20}$	1 $\frac{2}{20}$					

The counts made on the several dates plainly show that the plats in the first group, that is, Nos. I, II, IV, VI, and VII, had a decided advantage over the others in earliness of fruit production; those in the second group, that is, Nos. III and V, were about intermediate, while No. VIII fell far behind all the others. Plats of the first group reached their maximum square production about July 9; those in the second group about two weeks later; and plat VIII about a week later than the second.

The decided uniformity of the results of the counts on the several dates is noteworthy; also their conformity with the earliness as shown

by the first picking. The total weight of the cotton picked from the several plats bears out the results of the counts, for it is noticeable that the maximum square production on the unfertilized plats never reached as high as on those which were fertilized, and Plat VIII, which had ordinary treatment, was considerably below Plats III and V, unfertilized, but which were planted with King seed and thoroughly cultivated. The same effects are noticeable in the maximum boll production.

Bolls which are full grown by August 15, as shown by counts of injured and uninjured fruit, are practically safe from bollworm injury; hence the advantage of early-fruited varieties, early planting, fertilizers, and thorough cultivation may be readily seen: for on the above date Plats I, II, IV, VI, and VII show an average of $19\frac{1}{2}$ bolls per plant, which would be practically out of danger of bollworm injury. Of these $19\frac{1}{2}$ bolls there was an average of $4\frac{3}{4}$ bolls per plant open on that date. Plats III and V show an average of $18\frac{3}{4}$ bolls per plant practically out of danger, an average of $1\frac{7}{8}$ of these being open. Plat VIII had $9\frac{3}{4}$ bolls per plant out of danger, or less than half the number which on the fertilized plats would be quite sure of escaping bollworm injury.

PITTSBURG FARM.

The experimental farm at Pittsburg, Tex., on the plantation of Mr. J. F. Harrison, was located on a typical sandy soil of that section. It was supposed that fertilizers would exert considerable influence on the production of cotton on a soil of this character, and this feature of the work was emphasized. The land used was said to have been in cultivation continuously for the past sixty years. In 1902 it was planted to corn and in 1903 to cotton. The productiveness of the land was considered to be one-fourth bale per acre.

The accompanying plan shows the treatment of, and the results from, the respective plats involved in this fertilizer experiment:

Experimental cotton plats of the Department of Agriculture at Pittsburg, Tex., 1904.

Plat I. Five acres. Hetty seed. Planted April 13. Fertilized, R. P. C.^a 300 pounds per acre. Cultivated 8 times. Hoed 3 times. Yield, pounds seed cotton per acre, 1,403.8.	Plat III. Five acres. Hetty seed. Planted April 13. Fertilized, R. A. P.^c 320 pounds per acre. Cultivated 8 times. Hoed 3 times. Yield, pounds seed cotton per acre, 1,202.8.
Plat II. Five acres. Hetty seed. Planted April 13. Fertilized, C. B. G.^b 400 pounds per acre. Cultivated 8 times. Hoed 3 times. Yield, pounds seed cotton per acre, 997.8.	Plat IV. Five acres. Hetty seed. Planted April 13. Unfertilized. Cultivated 8 times. Hoed 3 times. Yield, pounds seed cotton per acre, 694.

^a R. P. C.—A commercial potash compound, analyzing—available phosphoric acid, 10 per cent; potash, 2 per cent.

^b C. B. G.—A commercial cotton boll guano, analyzing—available phosphoric acid, 8 per cent; potash, 2 per cent; nitrogen, 2 per cent.

^c R. A. P.—A commercial acid phosphate, analyzing—available phosphoric acid, 14 per cent.

The comparative earliness of the crop, the increase and value of the same, and the net gain by the use of fertilizers are shown more in detail for the respective plats in the table below:

TABLE V.—Showing treatment of, and results from, plats in Department of Agriculture's bollworm experimental farm at Pittsburg, Tex., 1904.

Plat number.	Variety of cotton.	Fertilizer and quantity used per acre.	Date of planting.	Times cultivated.	Times hoed.	Yield per acre in pounds of seed cotton.	Weights of seed cotton picked—					Increase per acre in pounds of seed cotton as compared with Plat IV.	Value of increase per acre at 3.14 cents per pound seed cotton.	Cost of fertilizer per acre.	Net gain.
							August 29-30.	September 7-19.	September 23-October 3.	October 10-28.	November 23-26.				
I	Hetty.	300 pounds. R. P. C.	Apr. 13	s	s	31,403.8	148.6	358.8	397.4	375.6	123.4	700.8	\$23.53	\$3.23	\$20.30
II	do..	400 pounds. C. B. G.	do..	s	s	997.8	158.6	310.6	266.4	162.2	70.0	303.8	10.07	4.60	5.47
III	do..	320 pounds. R. A. P.	do..	s	s	1,202.8	232.0	499.0	307.2	125.8	38.8	508.8	16.86	3.04	13.82
IV	do..	Unfertilized.	do..	s	s	694.0	.....	377.0	.....	297.6	19.4	.....	.....	.....	.....
Average price per pound lint cotton.....							11 $\frac{1}{8}$	10 $\frac{1}{16}$	10 $\frac{1}{16}$	9 $\frac{1}{16}$	9 $\frac{1}{16}$	.....	.....	.....	.....

Plats I and IV are compared graphically with respect to earliness and yield in figure 2.

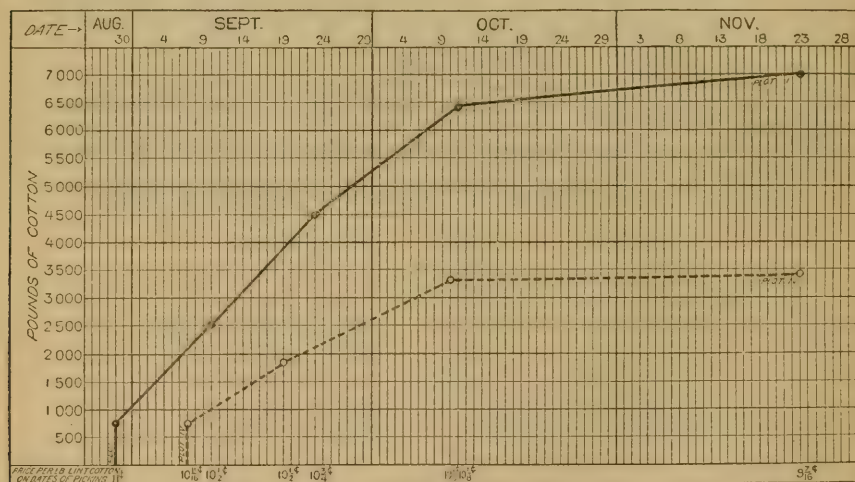


FIG. 2.—Diagram comparing Plats I and IV of the Pittsburg (Tex.) farm, fertilized and unfertilized, respectively, with regard to earliness and yield of seed cotton.

In connection with the above results as to final yield should be considered certain data relative to the rate of fruit production during

the season as determined by counts on different dates on 20 plants on each plat. The important results of these counts are indicated in the following table:

TABLE VI.—*Showing rate of fruiting on respective plats of Department of Agriculture's bollworm experimental farm at Pittsburg, Tex., 1904.*

Plat number.	Dates of examination.	Average number of squares per plant.	Average number of bolls per plant.				Average increase per plant in number of—				
			One-fourth-grown.	One-half to three-fourths-grown.	Full-grown.	Open.	Squares as compared with Plat IV.	One-fourth-grown bolls as compared with Plat IV.	One-half to three-fourths-grown bolls as compared with Plat IV.	Full-grown bolls as compared with Plat IV.	Open bolls as compared with Plat IV.
I	June 24	21 $\frac{6}{20}$	.....	.....	.....	.....	9 $\frac{16}{20}$	.....	.....	.....	.....
II	do.....	19 $\frac{8}{20}$	.....	.....	.....	.....	7 $\frac{18}{20}$	.....	.....	.....	.....
III	do.....	21 $\frac{11}{20}$	.....	.....	.....	.....	10 $\frac{20}{20}$	.....	.....	.....	.....
IV	do.....	11 $\frac{19}{20}$	.....	.....	.....	.....	.....	.....	.....	.....	.....
I	July 13	62 $\frac{3}{20}$	21 $\frac{8}{20}$	14 $\frac{11}{20}$	1 $\frac{1}{20}$	.....	164 $\frac{3}{20}$	2 $\frac{14}{20}$	1	2 $\frac{1}{20}$	.....
II	do.....	73 $\frac{8}{20}$	4 $\frac{20}{20}$	11 $\frac{13}{20}$	2 $\frac{3}{20}$	.....	274 $\frac{8}{20}$	2	1 $\frac{23}{20}$	2 $\frac{1}{20}$	.....
III	do.....	61 $\frac{14}{20}$	4 $\frac{4}{20}$	1 $\frac{13}{20}$	.....	.....	16 $\frac{3}{20}$	.....	.....	.....	.....
IV	do.....	45 $\frac{14}{20}$	2 $\frac{20}{20}$	1 $\frac{1}{20}$	.....	.....	.....	.....	.....	.....	.....
I	July 28	81 $\frac{11}{20}$	16 $\frac{3}{20}$	51 $\frac{8}{20}$	44 $\frac{2}{20}$	.....	15 $\frac{3}{20}$	5 $\frac{7}{20}$	14 $\frac{3}{20}$	2 $\frac{7}{20}$	.....
II	do.....	90 $\frac{19}{20}$	14 $\frac{11}{20}$	51 $\frac{8}{20}$	5 $\frac{9}{20}$	.....	24 $\frac{20}{20}$	31 $\frac{8}{20}$	1 $\frac{21}{20}$	3 $\frac{7}{20}$	.....
III	do.....	103 $\frac{17}{20}$	12 $\frac{10}{20}$	6 $\frac{5}{20}$	41 $\frac{11}{20}$	.....	37 $\frac{20}{20}$	1 $\frac{2}{20}$	14 $\frac{3}{20}$	2 $\frac{6}{20}$	.....
IV	do.....	66 $\frac{20}{20}$	10 $\frac{18}{20}$	4 $\frac{2}{20}$	2 $\frac{20}{20}$	.....	.....	.....	.....	.....	.....
I	Aug. 18	251 $\frac{19}{20}$	16 $\frac{3}{20}$	15 $\frac{3}{20}$	9 $\frac{5}{20}$	1 $\frac{19}{20}$	-8 $\frac{6}{20}$	1 $\frac{8}{20}$	317 $\frac{1}{20}$	411 $\frac{1}{20}$	7 $\frac{19}{20}$
II	do.....	312 $\frac{19}{20}$	20 $\frac{11}{20}$	13 $\frac{14}{20}$	10 $\frac{10}{20}$	4 $\frac{20}{20}$	-2 $\frac{20}{20}$	5 $\frac{8}{20}$	2 $\frac{20}{20}$	51 $\frac{19}{20}$	1 $\frac{19}{20}$
III	do.....	303 $\frac{19}{20}$	17 $\frac{20}{20}$	13 $\frac{14}{20}$	5 $\frac{10}{20}$	1 $\frac{18}{20}$	3 $\frac{20}{20}$	2 $\frac{20}{20}$	2 $\frac{20}{20}$	51 $\frac{19}{20}$	1 $\frac{19}{20}$
IV	do.....	334 $\frac{18}{20}$	14 $\frac{18}{20}$	11 $\frac{20}{20}$	4 $\frac{20}{20}$	2 $\frac{19}{20}$	.....	.....	.....	.....	.....

SUMMARY REMARKS CONCERNING THE EXPERIMENTS WITH CULTURAL METHODS.

In the case of field experiments involving questions of the character of those presented above, final conclusions may not be drawn as the result of one or even several years' tests. Variations in seasons and other conditions often produce results one year not verifiable the next; and what appears desirable for one character of soil may not be useful on another. The writers would, therefore, be entirely unwarranted in making specific recommendations, especially as regards the use of certain fertilizer elements, on the data secured in the course of last year's investigation.

Certain general statements are, however, apparently warranted. At the Pittsburg, Wills Point, and other experimental farms the use of fertilizers resulted in a notably earlier and larger crop of cotton, as compared with the unfertilized check plats.

On soils deficient in one or more of the three principal elements of plant food, namely, phosphoric acid, nitrogen, and potash, the application of the needed element or elements results in a more rapid and

larger growth of the plant and a consequent earlier and greater production of squares. It would appear that herein lies the principal value of fertilizers, as related to the production of an early crop.

On the Pittsburg farm, attention is called to the larger and earlier yields obtained from the use of a fertilizer containing 10 per cent of phosphoric acid and 2 per cent of potash, and from the use of 14 per cent acid phosphate alone, as compared with a complete fertilizer analyzing, phosphoric acid 8 per cent, nitrogen 2 per cent, and potash 2 per cent. On the Wills Point farm the largest yield was obtained from the use of 14 per cent acid phosphate. Plats I, II, and IV, however, show approximately the same total yield. The comparative earliness may be indicated from the following weights of seed cotton picked by August 23: Plat I, 2,325 pounds; Plat II, 2,029 pounds; Plat IV, 2,554 pounds. This gives again a slight balance in favor of an acid phosphate and potash fertilizer as to earliness of crop. It may also be mentioned here that in the fertilizer experiments in 1904, on the plantation of Capt. B. D. Wilson, Hetty, Tex., on rich "bottom" soil, the use of 400 pounds per acre of a phosphoric acid and potash mixture gave a considerably larger early and total yield of cotton than did the use of 300 and 450 pounds per acre, respectively, of phosphoric acid. The first picking from phosphoric acid and potash mixture plats, September 3, was 499 pounds seed cotton per acre. From the plat treated with 300 pounds acid phosphate, 354½ pounds of seed cotton per acre were secured; and from the plat receiving 450 pounds of acid phosphate the yield was 355½ pounds of seed cotton per acre. The total yield of seed cotton per acre from the respective plats was 1,387½ pounds, 1,153 pounds, and 1,280½ pounds.

It is, however, only intended to point out the usefulness, in general, of employing fertilizers in a system of cotton culture designed to produce a crop ahead of bollworm injury. The exact character of the fertilizer and the quantity per acre to be used are matters of further experimentation. The previously tabulated data in regard to fertilizers should furnish planters with a basis for experimentation by which they will finally arrive at conclusions true for their respective soils.

Of equal importance in the production of early cotton is the use of varieties with an inherent tendency to begin fruiting early in the growth of the plant, or low on the plant, and on which the joints are short. Observant planters need not be told of the great difference in fruiting habit of different varieties of cotton. The long-limbed sorts are necessarily later in setting squares, and they are also less prolific than those with shorter joints. The desirable qualities, as early fruiting, good staple, etc., may be perpetuated and improved by seed selection. Seasonal conditions, such as a shorter growing season, have led, in the northern part of the cotton belt, to the use of early-fruited, prolific varieties in those sections. Seed of such varieties, especially the King,

has recently been extensively planted in Texas on account of these characteristics, in both the bollworm and boll weevil infested regions. The importance of the use of selected early-fruited varieties, as compared with the native "run-down" gin seed, was well illustrated in the investigations during 1903. On the plantation of Capt. B. D. Wilson, at Hetty, Tex., under conditions of severe bollworm injury, early planted King seed produced an average of 1,348 pounds per acre of seed cotton, as against 187 pounds per acre of early-planted but late-maturing gin seed. The advantage of early planting is emphasized by results secured on various farms. On the Wilson farm in 1903 early-planted King with thorough cultivation gave 1,348 pounds seed cotton per acre, as compared with 360 pounds per acre from late-planted King also with thorough cultivation.

Early and thorough cultivation is another important factor in the production of early cotton. Plants should be chopped out as early as practicable to admit of free branching and consequent square production. The fertility of the soil, either native or introduced by means of fertilizers, may be used by plants only in solution. Consequently, for the conservation of moisture and other reasons, timely and frequent cultivations are of the utmost importance.

TRAP CROPS.

Attention has been elsewhere called to the decided preference of bollworms for corn as compared with other plants upon which it is known to feed. This preference permits of the use of corn in a way calculated to protect cotton from injury.

The corn should be planted in belts through the cotton field at a time that will result in its being in tassel and silk about the first of August. By this time moths are developing from larvæ matured in the roasting ears of neighboring corn which has now begun to ripen and is no longer attractive to the moths for egg-laying purposes. In the natural course of events, the moths migrate to cotton fields, where they deposit the bulk of their eggs. Finding these belts of corn in tassel and silk, however, they deposit on them the greater part of their eggs, and correspondingly neglect the cotton plants. The September generation of larvæ is sometimes a source of considerable injury, especially to very late cotton. Corn may easily be brought into silk so as to attract moths of this generation by planting only a portion of the belts through the cotton fields at the time of first planting and then completing the work two or three weeks later. The same results may be secured by planting patches of corn here and there over the plantation, following crops of oats, wheat, or Irish potatoes. Cowpeas are very attractive to bollworm moths, owing to their fondness for the nectar profusely secreted by this plant. Thus the corn

trap rows may be made more effective by planting rows of peas alternately with rows of corn. The peas should come into full bloom at the time the corn is silking. This will necessitate planting the peas about the time the corn appears above the ground. The advantage gained by the use of trap crops can not be expressed in pounds of seed cotton, as it is impossible to arrange a test so that the area left for comparison will be subjected to the same conditions without having it adjacent and consequently equally subject to protection by the corn. Bollworm moths fly freely, and are therefore attracted to fresh corn from a considerable distance, and the influence of the trap rows is thus quite general.

During 1903 tests of corn trap crops for protecting cotton against the more destructive August generation of bollworms were made at Calvert and Wills Point, Tex. Early in August the number of eggs upon 8 typical plants in the trap rows at Wills Point was found to be, on an average, 495 per plant, 804 eggs being the maximum number found on a single plant. No account was taken of eggs deposited on plants previous to or succeeding this time. From these figures some idea may be gained of the vast number of eggs which are thus diverted from cotton. In 1904 tests of corn as a trap crop were made at Sulphur Springs, Quinlan, and Hetty, Tex., and at Shreveport, La. The same general plan was carried out in all of the above localities, protection from the August brood only being sought. Belts from 10 to 40 feet wide extending across the field were left unplanted at the time of planting cotton, and these were seeded to Mexican June corn by June 1 in rows from 5 to 6 feet apart. Ten days later cowpeas were planted between the rows of corn, thus leaving ample room for cultivation. The corn was planted in about the proportion of 10 rows to 40 rows of cotton, and the individual fields varied from 20 to 40 acres.

The following table, computed from counts made of the number of eggs on 20 typical plants in trap rows on the farm of Mr. J. T. Hargrove, Sulphur Springs, Tex., will give an idea of the number of eggs kept from the cotton by a few acres of trap corn. The figures show the average number of eggs for each plant and the average number on the various portions of the plants:

TABLE VII.—*Distribution and average number of bollworm eggs on corn.*

Date of examination.	Number of eggs on—					Condition of corn.
	Entire plant.	Leaves.	Sheaths.	Tassels.	Silks.	
July 28	338.4	88.85	55.55	64.93	129.1	Many plants not in silk. Corn in roasting ear; silks drying.
August 16	52.55	12	7.85	10.8	21.9	

During a year of greater bollworm abundance the number of eggs that would be deposited on corn would doubtless far exceed the numbers here given. The number of eggs occurring on an acre of trap corn at one time, as based on the above figures, is surprisingly great. Taking the average number of eggs per plant on July 28; as given in the table, the protection afforded by the plants on a single acre may be calculated in a theoretical way. Assuming the corn rows to be 6 feet apart and the plants $1\frac{1}{2}$ feet apart in the row, there would be on an acre 4,840 plants. On the average of 338.4 eggs per plant, as found above, there would be 1,637,856 eggs distributed over the acre of corn. By a series of observations it has been determined that a single bollworm feeding freely on cotton will destroy on an average 8 squares, 1 flower, and $1\frac{1}{2}$ bolls during the course of its growth. Assuming that all of the fruit destroyed would have eventually matured, there would be a total destruction of 17,470,464 bolls. On an average of 70 bolls to the pound of seed cotton, this would mean a destruction of 249,578 pounds of cotton in the seed, or at the rate of 1,500 pounds seed cotton to the bale, 166 bales.

It must be remembered, however, that in the above calculations it was assumed that from every egg a mature larva would develop. This would be far from the case in reality. In fact it has been observed that on an average but one larva reaches maturity from about 50 eggs deposited on corn. It was further assumed that all of the squares and flowers injured would have otherwise reached maturity, which in fact would not be the case, as many squares and young bolls are shed by the plants on account of unfavorable weather or other conditions. However, after making due allowance for all of these conditions, the benefits to be derived from a proper use of corn as a trap crop are seen to be very great.

It might appear at first sight that the practice of furnishing the bollworm with an abundance of its preferred food would simply result in its greater increase and consequent destructiveness. This, however, does not result, for when the eggs are concentrated on the corn plants, as on the silks, they are very largely destroyed by a certain parasite and by predaceous enemies, and the larvæ hatching from these eggs are largely killed by the cannibalistic habits of the bollworms themselves. Out of some 15 to 30 young larvæ which may usually be found in a recently silked ear of corn, but one or two bollworms will eventually reach maturity.

Numerous instances have come under the observation of the writers where planters, in attempting to make use of trap crops, have made the mistake of planting the corn at the usual time in the spring. The result has been, that the cotton has suffered greater injury than would otherwise have occurred. The success of the trap crop idea as here

considered depends entirely on having the corn in tassel and silk on or about the first of August, and it must be planted considerably later than the normal time of planting corn in the spring. June corn planted the last of May or first of June, with good cultivation, will be silking and tasseling freely by August 1.

The greatest benefit will come from the use of corn as a trap crop in its general adoption by the planters of a neighborhood. In the case of large plantations it is quite possible to adopt a system of growing late corn, after oats, wheat, or other early-maturing crops, which will attract the bollworms from the plantation generally. An instance of this practice may be cited on the plantation of Mr. F. L. Maxwell, of Mound, La. It has been the practice of this gentleman to grow small areas of late corn after oats here and there over the plantation to the almost complete protection of his large cotton crop.

USE OF ARSENICAL POISONS.

The opinion prevails more or less generally among cotton planters that the bollworm may not be successfully poisoned, by reason of the fact that it bores to the interior of squares and bolls, and does not feed on the exterior parts of the plant to any extent. Such a belief is true only of the later stages of the larva. The average planter seldom has his attention attracted by so small a creature as a newly hatched bollworm, and it thus results that the habits of the insect during its early larval existence are practically unknown to him. This unobserved period in the development of the larva is the only time when poisons may be expected to exert any considerable influence in bollworm control.

From extended studies of the egg-laying habits of the moth and the actions of the newly-hatched larvæ there is every reason to believe, on theoretical grounds, that, by the application of poison to cotton at about the time the eggs of the large August generation begin to hatch, the injury from this insect may be greatly reduced. A series of observations made during the summer of 1903 on the distribution of eggs on cotton plants, as determined by watching the moths while ovipositing, showed that 73 per cent of the eggs were so placed that the resulting larvæ would be readily susceptible to poison. By carefully examining several plants, 65 per cent of the eggs were found to be on other parts than the squares, flowers, and bolls. During 1904 similar records were made by watching the moths ovipositing in cotton fields. The combined record of 25 moths is given below:

Distribution of bollworm eggs upon cotton plants.

	Eggs.
Leaves, upper surface.....	191
Leaves, lower surface.....	194
Squares.....	326
Flowers.....	110
Bolls.....	120
Growing tips.....	46
Stems.....	64
Petioles.....	29
Weeds.....	20
Objects on ground.....	21
Dead leaves.....	20

The total number of plants oviposited on by these 25 moths was 1,175. All larvæ hatching from eggs deposited elsewhere than on the squares and flowers may, for reasons to be given, be considered as capable of destruction by poison. Therefore, of the 1,141 eggs deposited, 705, or about 62 per cent, would fall in this class.

On account of the important bearing on the subject of poisoning, as before mentioned, the habits of the newly hatched larvæ have been quite carefully studied. Immediately upon its escape from the egg the little larva devours its deserted egg-shell and soon afterwards begins a restless search for food. If it hatches from an egg placed upon a square or flower, it may soon effect an entrance, but if situated elsewhere, as on a leaf, it may wander about here and there, frequently tasting or rasping the epidermis of the leaf or other portion of the plant where it may be, in its efforts to find suitable food.

This apparently aimless search is often continued for several hours. The same path is often crossed and recrossed many times with short intervals of surface feeding along the way. Many of these minute larvæ perish in their attempts to find suitable food; others succeed in reaching some tender-growing portion of the plant, as the terminal bud of unfolded leaves, which is soon penetrated. Although considerable traveling may be done later in the search for fresh food, but little food is taken on the surface. Larvæ which hatch from eggs placed upon bolls may rasp the epidermis but are unable to enter except in case of the smallest bolls. Therefore these, as well as larvæ from eggs placed upon the leaves, petioles, stems, etc., are compelled to seek more tender portions. This period of what might be called external feeding varies greatly in different individuals, lasting, as a rule, probably from a few hours to a day, or even more.

Considering the above facts, the necessity of applying poisons at the proper time is apparent. No arbitrary date may be given, owing to the variability of the time at which the larvæ begin to hatch in destructive numbers in different localities. However, the planter may determine this time approximately by careful observation. When

moths are seen to be present in any considerable numbers in cotton fields, the poison should be applied immediately. The moths do not become abundant in the fields, as a rule, until the August generation appears, which is during the last few days of July or the first week of August. As has been stated, poisons should be applied when the eggs begin to hatch in numbers, about the first of August, and not when the larvæ have attained considerable size, as they have three weeks later. The first application should be made, as a rule, about the last of July, and should be repeated in about a week or ten days. In case of rain following an application, it should be repeated immediately. Sometimes a third treatment at a later date is desirable. When the dusting method is employed, the application should be made early in the morning or after a shower, as the moisture on the plants is important to retain the dust as it comes in contact with the foliage and other parts.

To illustrate the efficiency of poison when applied at the proper time in killing newly hatched larvæ, the following is of interest: The results were obtained by Mr. C. T. Brues in a small experiment conducted at the laboratory at Paris, Tex. On September 17, two plants which were squaring freely were covered with wire screen cages, one plant having previously been lightly dusted with paris green diluted with dry slaked lime. About 200 hundred eggs which were ready to hatch were placed upon each plant. Observations were made each day of the number of fruits injured until October 16, when all of the surviving larvæ had entered the soil to pupate. Only 1 square was injured during this period on the poisoned plant, while on the unpoisoned check plant 31 squares, 2 flowers, 12 small and 2 large bolls were destroyed. Notwithstanding the fact that there were heavy rains during the nights of September 20 and 21, the destruction of the larvæ by one application was practically complete. In these instances the larvæ all hatched practically at the same time and shortly after the poison had been applied. Such uniformity in hatching would not be the case in the field, and therefore such complete extermination could not be expected.

As between the dusting and spraying methods of applying poisons, the former seems more practicable. The main objection to the use of a spray is the difficulty usually found in securing water in proximity to fields, and the greater time required in the application of poisons in liquid condition. Geared machinery may be secured for poisoning by either method, but the rather primitive way so largely used in combating the cotton caterpillar, by dusting the poison through bags tied to each end of a pole and carried by a man on horseback, has a decided advantage on account of cheapness of apparatus. By this means some 20 to 25 acres may be poisoned during the few hours suitable for this work in the early morning and late evening. Where the poison is

dusted over the plants, from 2 to 3 pounds of Paris green should be used per acre, and in spraying the poison should be used at the rate of 1 pound to each 50 gallons of water. Fifty gallons of water will spray approximately 1 acre of cotton.

In purchasing poisons reliable brands should be insisted upon. Where large dusting machines are used, it will be more economical to mix the Paris green with 3 or 4 times as much flour, or even more, or with sifted, dry, or air-slaked lime.

During the summer of 1903 very favorable results were obtained in poison experiments at Hetty and at Calvert, Tex., by reason of the great abundance of bollworms at that time. At Hetty, Paris green was applied by means of bags on a pole. In this case a net gain of \$5.79 per acre was realized. At Calvert, Paris green was applied both as a spray and in the dust form. By the former method a net gain of \$6.99 was secured, and by the latter a net gain of \$4.44. Although several experiments were conducted during the season of 1904, no decided results were obtained owing to the more general absence of bollworms in destructive numbers.

In north Texas especially, there is a decided prejudice on the part of cotton pickers against picking cotton from fields that have been poisoned. Several reported instances of fatal poisoning, through cuts or sores on the hands, are cited in support of these objections. The writers have investigated several of these reports of poisoning, and no evidence has been found to warrant the conclusion that there is any danger to pickers from the proper use of poison in bollworm control. Harmony of action in poisoning on the part of planters would largely do away with the present prejudice of pickers against this work.

INEFFECTIVE METHODS OF BOLLWORM CONTROL.

Attention has at various times been called to the inefficiency of certain methods often used by planters with a view to controlling the bollworm. A common error is in the burning of lights to attract and destroy the moths, and one less frequently employed is the use of poisoned sweets placed in pans here and there in the cotton fields.

During the past two years, under varying conditions of weather, both of these procedures have been thoroughly tested. As a result the previously demonstrated futility of such work has been fully verified. Attention is called to the uselessness of such operations that the planter may avoid this needless expense.

RECOMMENDATIONS.

The work of the Bureau of Entomology during the past two years has shown that by the adoption of certain cultural expedients, desirable

in themselves, a satisfactory crop of cotton may be grown during years of severe bollworm injury. This requires, for best results, the adoption of all methods useful in the production of an early crop, and is based on the fact that cotton is not attacked in force by bollworms until the corn in surrounding fields begins to harden, which in general is about the first of August.

In the cultural system, by which profitable crops of cotton may be grown in spite of the presence of the bollworm, the following procedures are important: (1) Thorough plowing of the land during the fall or winter months to destroy as many as possible of the hibernating pupæ in the soil; (2) the use of seed of early-fruited varieties of cotton; (3) the use of fertilizers to hasten and increase the growth of plants and the formation of fruit; (4) planting at the first practicable date in the spring; (5) early and frequent cultivation.

The use of corn as a trap crop is recommended. In planting cotton leave vacant strips across the fields every 200 or 300 feet sufficiently wide for planting 10 or 12 rows of corn. The corn should be planted so that it will be in prime silking condition about August 1. Under favorable conditions of rainfall and with good cultivation, Mexican June corn planted by June 1 will be in proper condition by August 1. Plant cowpeas in the corn belts so that the peas will be flowering at the time the silks and tassels appear on the corn, thus furnishing food for the moths and keeping them out of the cotton fields. Much the same benefits may be secured by planting patches of late corn on different parts of the plantation, as after oats, wheat, etc. In all cases peas should be planted in the corn. The corn thus grown may be harvested in the usual way. *The corn should not be planted for trap-crop purposes in belts through the cotton field at the usual time of planting in the spring. To be of value in bollworm control it should not be in silk and tassel until about August 1.*

During seasons of severe bollworm injury, poisons may be profitably used on cotton. Poisons should be applied late in July and early in August to secure the maximum destruction of young larvæ of this generation. Two or three applications may be necessary at intervals of a week or ten days. After rains the application should be immediately repeated. Paris green at the rate of from 2 to 3 pounds per acre for each application will be satisfactory. It is best applied in a dry condition, either pure or mixed with cheap flour, and dusted over the plants by the usual pole-and-bag method or by means of a dust-spray machine.

FARMERS' BULLETIN No. 216.

THE CONTROL OF THE BOLL WEEVIL, INCLUDING RESULTS OF RECENT INVESTIGATIONS.

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., February 3, 1905.

SIR: I transmit herewith a manuscript entitled "The Control of the Boll Weevil, Including Results of Recent Investigations," prepared by Mr. W. D. Hunter, special agent of this Bureau in charge of experimental work with the cotton boll weevil. This paper will replace Farmers' Bulletin No. 189. It contains the previous recommendations of the Bureau of Entomology regarding the means of mitigating the damage by this very serious pest, with such minor modifications as have been made necessary by the work of the past season. In addition, various topics, such as the territory infested, the present status of State quarantines against the boll weevil, and other matters, are considered. I recommend that it be issued as a Farmers' Bulletin.

Respectfully,

HON. JAMES WILSON,
Secretary of Agriculture.

L. O. HOWARD,
Chief of Bureau.

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THE CONTROL OF THE BOLL WEEVIL.

RECOMMENDATIONS.

The work of the Bureau of Entomology for several years has indicated that there is not even a remote probability that the boll weevil will ever be exterminated. As a matter of fact, no injurious insect has ever been exterminated. Some species, like the Rocky Mountain locust in this country, have died out more or less on account of climatic influences, and reasonably effective methods of combating others, like the Phylloxera in France, have been perfected.

Although the very large yields of cotton of former times may no longer be possible in the region now infested by the boll weevil, it is entirely feasible to produce cotton at a margin of profit that will compare favorably with that resulting from the production of most of the staple crops of the United States by following what has become generally known as the cultural method. This method consists of the following changes and modifications of the system of cotton raising, made necessary by the boll weevil. It was originally suggested by a careful study of the life history and habits of the pest, and naturally any improvements that may eventually be made will be the result of a continuation of that study. It has now been tested successfully on a large scale by the Bureau of Entomology, as well as by many planters, during three seasons. Of greatest advantage is the reducing of the numbers of the weevils by the destruction of the plants in the fall. The advantage thus gained is followed up by bending every effort toward procuring an early crop the next season.

(1) Plant early. If possible, plant seed of the varieties known to mature early, or obtain seed from as far north as possible. This recommendation is made as a suggestion for the benefit of those planters who have not taken care in the selection of the cotton seed for planting on their plantation. By far the best method for obtaining early seed is by selection in the field.

It is much better to run the risk of replanting, which is not an expensive operation, than to have the crop delayed. The practice of some planters of making two plantings to avoid having all the work of chopping thrown into a short period is very bad policy from the boll-weevil standpoint.

Early cotton of improved varieties has yielded from two to three times as much as native cotton under the same conditions, and in many cases much more. Planted at the same time, the early varieties begin to bloom much earlier than native cotton.

Early-planted fields of either native or improved varieties have almost invariably yielded twice as much as late-planted ones.

The early varieties, in general having a small stalk and short tap-root, are adapted only for rich soil. They also fail to grow well in the very light, drifting sandy loams of many of the river valleys of Texas, which, in long seasons before the advent of the boll weevil, often produced the largest yields. In these situations early varieties will yield but little more than native cotton.

(2) Cultivate the fields thoroughly. The principal benefit in this comes from the influence that such a practice has upon the constant growth and consequent early maturity of the crop. Very few weevils are killed by cultivation. Much of the benefit of early planting is lost unless it is followed by thorough cultivation. In case of unavoidably delayed planting, the best course for the planter to pursue is to cultivate the fields in the most thorough manner possible. Three choppings and numerous plowings constitute the thorough system of cultivation that is made necessary by the boll weevil. The old plantation rule for the cultivation of cotton, "Once a week and once in the row," is an excellent one.

(3) Plant the rows as far apart as experience with the land indicates is feasible, and thin out the plants in the rows thoroughly. On land which in normal seasons will produce from 35 to 40 bushels of corn the rows should be 5 feet apart. Even on poor soil it is doubtful if the distance should ever be less than 4 feet.

(4) Destroy, by plowing up, windrowing, and burning, all the cotton stalks in the fields as soon as the weevils become so numerous that practically all the fruit is being punctured. This will generally not be later than the first week in October. Merely cutting off the stalks, by means of the triangular implement used for that purpose throughout the South, is by no means as effective as plowing, because the stumps remaining give rise to sprouts which furnish food until late in the season to many weevils that would otherwise starve. The plowing, moreover, serves to place the ground in better condition for early planting the following spring. In some cases turning cattle into the fields is advisable. Aside from amounting to a practical destruction of the plants, grazing of the cotton fields furnishes considerable forage at a time when it is generally much in demand. Nevertheless, cattle should never be turned into cotton fields in which Johnson grass has become started.

Recommendations 1, 2, and 3 are all aimed toward avoiding damage by hastening the maturity of the plants and do not involve the actual destruction of the weevils. Recommendation 4, however, reduces the numbers of the pests by destroying the very great proportion developing late in the fall, and is consequently directly remedial.

(5) It is known that at present fertilizers are not used to any considerable extent in cotton producing in Texas. There is, nevertheless, no doubt

that they should be—not that the land is poor, but that earlier crops may be procured. At present it is sufficient to call attention to the fact that it has been the uniform experience of experiment stations and planters in the eastern part of the belt that certain fertilizers, especially those involving a large percentage of phosphoric acid, have a strong tendency toward hastening the maturity of the plants.

The recommendations above made constitute the essential steps in the cultural system of averting damage by the boll weevil. In addition to these steps, however, all operations which assist in the growth of the crop are of decided advantage in regions infested by the boll weevil. There is thus a distinction between the cultural system of averting damage by the boll weevil and the proper system of cultivation of cotton. The terms are by no means synonymous. As a matter of fact the cultural system of averting damage by the boll weevil in some cases implies operations that would not be the proper ones in all cases for the production of the largest crop were the pest not present. This is especially the case in the early fall destruction of the plants, and also to some extent in the selection of early maturing varieties and in early planting itself.

A number of devices are possible for hastening the maturity of the crop in addition to those mentioned. For instance, thorough preparation of the land before planting is of very great importance; the packing of the soil by means of a roller immediately after the seed is planted insures rapid germination, and consequently also assists in advancing the maturity of the crop.

Necessarily the proper application of fertilizers is a complicated matter. Only the most general rules are possible for all conditions. The different soils on single farms require different compositions. Nevertheless, it can be stated that acid phosphate is the principal ingredient that the cotton plant requires, and that it has a very important function in hastening maturity. It also largely controls the action of the other essential elements, nitrogen and potash. The work of the southern experiment stations has shown that the nearest approach to a general formula for all soils is one that provides 10 per cent of available phosphoric acid, 3 per cent of ammonia, and 3 per cent of potash. This proportion is reached approximately by mixing 1,200 pounds of acid phosphate with 600 pounds of cotton-seed meal and 200 pounds of kainit.

The cultural means of obtaining an early crop, such as thorough preparation of the soil, selection of variety, early planting, fertilization, and cultivation will be dealt with fully in a Farmers' Bulletin, by Dr. R. J. Redding, director of the Georgia Agricultural Experiment Station, which will soon be issued.

INTRODUCTORY.

The present bulletin is designed to bring together discussions of some of the features of the boll weevil problem in the United States that are of most immediate interest. Among such matters are the more recent developments regarding (1) the cultural system of avoiding damage by the pest, (2) the territory affected, (3) the loss occasioned during the season of 1904; (4) the present status of quarantine regulations, and (5) some minor matters. Some information, as, for instance, the description of the weevil and some portions of the discussions of the damage caused by the pest, are reproduced from Farmers' Bulletin No. 189, which was published in January, 1904. It is not intended in the present bulletin to include all of the results of the experimental work conducted during the season. In a general way, the work of this season has demonstrated the value of the recommendation that has been made previously. Any modification of the present approved system of controlling the pest must be the result of the continuation of experimental work during a series of seasons. Some modifications have been suggested by the work during the past season, but before definite general recommendations can be made it will be necessary for the experiments to be repeated during other seasons when the climatic conditions may be essentially different. It is the purpose of the Bureau of Entomology to incorporate the results of all this experimental work as soon as possible in an extended account of all that is known concerning the methods of combating the pest. The present publication includes all recommendations which have been demonstrated to have a general bearing and to be applicable to all portions of the region now infested.

The experimental field work of the Bureau during 1904 was done on experimental farms at a number of localities in Texas, where local conditions presented special problems in the attempt to control the boll weevil. The following is a list of the experimental farms which were in operation:

County.	Planter.	Acreage.
Anderson.....	B. H. Gardner	100
Bexar	J. M. Styers	40
Karnes	W. H. Leekie	68
Limestone.....	J. L. Cogdell.....	65
Navarro.....	R. Beaton and W. T. Ferguson	94
Robertson.....	W. C. Anderson and E. S. Peters	225
Travis	Jefferson Johnson	100
Victoria.....	S. G. Reed and W. T. Tipton	85
Washington.....	J. E. Roult	100
Wharton.....	A. P. Borden	100
Williamson.....	C. C. Hooper	100

This work was conducted under contracts, according to which the planter agreed to prepare the soil, plant, and care for the crops in

accordance with the directions of the Bureau of Entomology. The prime object in the location of a farm at any particular point was to obtain typical conditions for an area which possessed characteristics that differentiated it from other cotton-producing areas in Texas. The most sharply defined of the different weevil regions in Texas is the portion of the State where volunteer or seppa cotton exists normally. The green parts of the plant persisting through the winter furnish the weevils an abundance of food in this region, of which they are deprived in other parts of the State. The consequence is that an unusually large number pass the winter successfully. Damage consequently begins in the fields earlier the following season here than elsewhere. This area normally extends about as far north as to a line between San Antonio and Houston. Another quite distinct region as regards its effect upon the habits of the boll weevil is found in the valley area of the central portion of the State. Between the latitudes of Navasota and Waco, approximately, there is a region in which no volunteer or seppa cotton is normally present. Nevertheless, the long season of growth of the plants furnishes the weevil food and means of reproduction until very late in the season. The cotton fields have generally all been cleared from forest land. There is consequently an abundance of timber which furnishes ideal cover for the hibernating weevils. In this region it has been the practice to devote exceptionally large areas or individual plantations to cotton. This is the result of the fact that cotton has been the most certain crop that can be produced, and that there are decided restrictions to diversified farming. There is not the opportunity which occurs south of this region for the cultivation of sugar cane and rice, and at the same time wheat and some other cereals which grow well north of the region under consideration do not prosper here. The limits of diversified farming are further restricted by the fact that many soils are not suitable for the cultivation of corn. The labor and general economic conditions have become centered in the production of one crop, and this has a very important bearing on the application of the cultural system. There is another distinct region which comprises the river valley area of the northern portion of the State. The hill region of central Texas, the prairie region of west central and northern Texas, the east Texas pine woods region, and the irrigated region of the western portion of the State also furnish peculiarities which cause the habits of the weevil to be modified, and consequently change materially the necessary means for controlling it. Of course there are many other regions in Texas where local conditions, as of soil, might bring about subdivisions of the regions that have been mentioned. However, these strictly local conditions concern themselves more with changes in the simple cultivation of the crop than with changes in the general system of mitigating damage by the boll weevil.

DESCRIPTION OF THE BOLL WEEVIL.

The following account of the means for identifying the boll weevil is taken mainly from Farmers' Bulletin No. 189.



FIG. 1.—Cotton boll weevil: *a*, beetle from above; *b*, same, from side—about five times natural size (original).

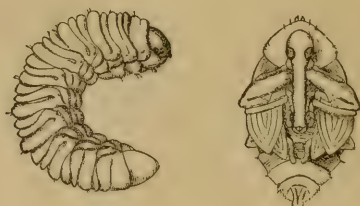


FIG. 2.—Cotton boll weevil: larva at left, pupa at right—about five times natural size (original).

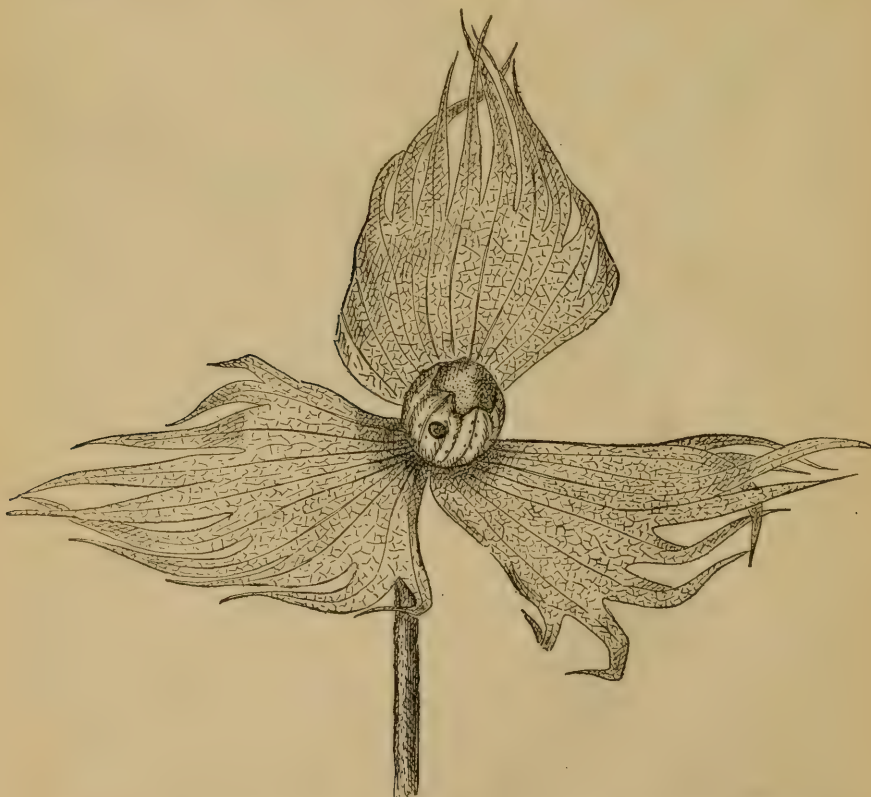


FIG. 3.—Cotton square flared, showing egg puncture of boll weevil—natural size (original).

Every intelligent planter in the weevil-infested area should be able to determine the presence of the pest by its appearance and the evidences of its work; but planters who have never seen it may often be in doubt as to whether some insect found damaging the crop is the boll weevil, or whether flaring and falling of the squares is caused by some other unseen insect pest or by climatic conditions. For the benefit of planters outside of the present weevil territory, in regions where the pest is more or less likely to be found at any time, the following description of the insect and its work is given. It is believed that this description will enable any planter to determine whether the pest is at



FIG. 4.—Cotton square cut open, showing boll weevil larva in position—natural size (original).

work in his field, so that he may take the necessary steps to fight it at the earliest moment.

The adult weevil averages about one-fourth of an inch in length, ranging from one-eighth to one-third inch, with the breadth about one-third of the length. This measurement includes the snout, which is about one-half of the length of the body. The color is a grayish or a yellowish brown. The general form will be understood from fig. 1. The insect exists in four stages—egg, larva, pupa (fig. 2), and adult. All the stages, except the adult, occur only within the cotton square or boll. The egg is deposited by the female weevil in a cavity formed by eating into the fruit of the plant (fig. 3). It hatches, under normal

conditions, in about 3 days, and the grub immediately begins to feed. In from 7 to 12 days the larva or grub passes into its pupal or transformation stage, corresponding to the cocoon stage of the silkworm. This stage lasts from 3 to 5 days. Then the adult weevil issues, and in about 5 days begins the production of another generation. Climatic conditions cause considerable variation in the duration of these stages, but on an average it requires from 2 to 3 weeks for the weevil to develop from the egg to the adult. The plainest indication of the presence of the weevil in a cotton field is the flaring (fig. 3) and falling of the squares or forms, which takes place generally between 5 and 10 days after the egg is deposited. However, as all planters are aware, heavy rains after drought, as well as other climatic conditions, have the effect of causing the squares to fall. If the planter should observe an unusual shedding of the fruit, he may easily determine the cause by gathering a few of the fallen squares. If, upon cutting open these squares, he finds a small, whitish, curved grub (fig. 4), there can be little doubt that the cause of the trouble is the boll weevil. Specimens should then be securely packed and sent to an entomologist for final determination.

TERRITORY AFFECTED.

During the season of 1904 the normal increase in infested territory occurred. About 15,000 square miles, representing approximately an area devoted to the cultivation of cotton of 900,000 acres, the normal production from which would be in the neighborhood of 350,000 bales, became invaded for the first time. This increases the infested area in the United States at present to about 32 per cent of the total cotton acreage.

One of the most interesting features of the situation during the past season has been the fact that the infested territory has been extended eastward much more rapidly than northward. Careful examinations of the portions of Indian Territory which the boll weevil is likely to reach first have failed to reveal any infestation. In fact, on the north the limitation of the infested territory remains practically the same as last year. This applies, however, only to the total infested area in which even isolated colonies of the pest have been found to exist. There has been a gradual northward advance of the limits of the region of what may be termed "gross infestation;" that is, where the weevils are to be found in considerable numbers in all cotton fields. This advance has extended from about the latitude of the northern portion of Ellis County to the latitude of the southern portions of Denton and Collin counties, a distance of about 36 miles.

The situation mentioned in the preceding paragraph leads to speculation as to whether the pest has not reached a northern limit beyond

which its spread will be prevented or at least checked by climatic conditions. During the past year it has been found that there is at least one full generation less at Terrell, Tex., than at Victoria, Tex., 275 miles south of that place. With the very rapid multiplication of the pest, this means greatly lessened actual damage. The time when the maximum number of weevils per acre is produced is made considerably later, with a consequent manifest advantage to the crop. The lessened number of generations is due to three principal factors: (1) Later emergence from hibernating quarters; (2) greater time required for the development of the several stages; and (3) the earlier date of the first killing frost. These considerations would, theoretically at least, cause the weevil problem to become a much less serious one in extreme northern Texas than it has been in regions that have heretofore been infested, and the observations of the last season bear out this supposition. However, it is to be expected that there will be some adaptation on the part of the weevil to the climatic conditions in newly invaded regions, and this introduces considerable uncertainty in any prediction regarding future damage. The present indications are that the greatest damage by the pest will always be in the region south of the latitude of Dallas, Tex.

To the east there has been a general extension of the infested territory of about 50 miles. The pest has been found east of the Red River at three points in Louisiana, namely, Lockwood, Grand Ecure, and Shreveport. In that State the greater portion of six parishes is known to be generally infested, while in three others the weevils are known to occur in certain localities. Special opportunities for studying this spread were given by the cooperation which the Bureau of Entomology carried on with the Louisiana crop pest commission. It was found that there was an advance early in the fall due to the fact that the weevils were carried from place to place in seed for planting purposes. This was followed by considerable increase in territory due to the conveying of the seed cotton to the gins, and, most important, there was an advance due to an actual migration in August and September, which in many cases reached far beyond the limits of the territory covered by the first two means which have been mentioned.

At frequent intervals during the past season (1904) accounts of the occurrence of the boll weevil at various points far beyond the limits of the infested territory indicated upon the accompanying map (fig. 5) have appeared in the newspapers. It seems likely that the pest may at any time be carried to points far outside of the present infested territory through the ordinary shipments of cotton products. There is also some possibility that persons who have received live specimens from Texas for experimentation with supposed remedies may inadvertently introduce them into uninfested fields. In consequence of these probabilities, the Bureau of Entomology has devoted special

attention to the reported occurrence of the weevil outside of the region indicated upon the accompanying map. A number of reports originating in Louisiana, Arkansas, and Indian Territory have been investigated by entomologists connected with the Bureau. Through cooperation with State and station entomologists the Bureau has obtained specific information about reports originating in Georgia,

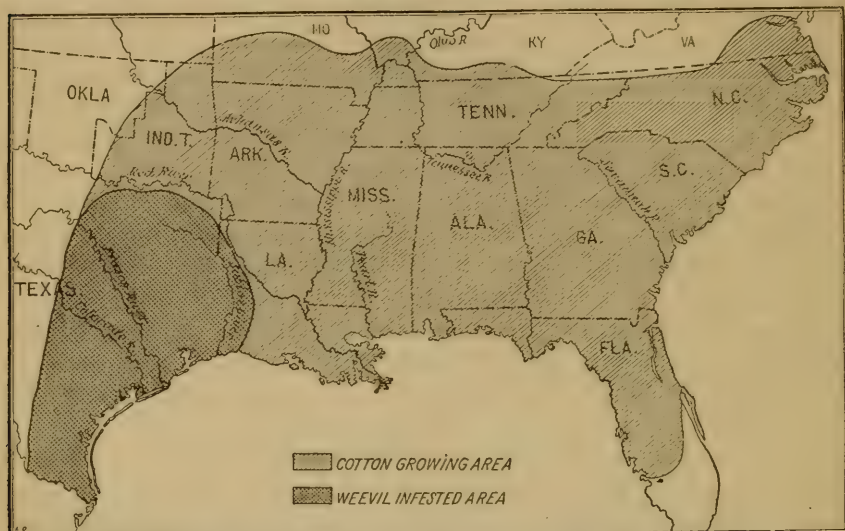


FIG. 5.—Map of territory infested by boll weevil.

South Carolina, and elsewhere. All such reports investigated have been found to rest upon a mistaken identification of some of the numerous insects more or less resembling the boll weevil which have been found in cotton fields.

DAMAGE CAUSED BY THE BOLL WEEVIL.

The following table, reproduced from Farmers' Bulletin No. 189, shows the great damage caused by the boll weevil:

Comparative estimate of amount of damage by cotton boll weevil.

Typical counties in which weevil was not present in 1899, but was present in 1902.			Typical counties in which weevil was not present in either 1899 or 1902.		
County.	Product in commercial bales.		County.	Product in commercial bales.	
	1899.	1902.		1899.	1902.
Caldwell.....	47,473	23,133	Montague.....	15,064	16,981
Colorado.....	30,923	11,493	Cooke.....	11,905	11,012
Fayette.....	73,238	31,200	Grayson.....	40,871	54,087
Gonzales.....	44,131	25,351	Fannin.....	59,802	70,540
Grimes.....	26,541	12,135	Lamar.....	49,193	59,269
Lavaca.....	42,484	22,906	Wise.....	17,556	18,869
Montgomery.....	10,272	3,660	Denton.....	20,381	24,541
San Jacinto.....	8,826	3,044	Collins.....	49,077	47,344
Travis.....	60,078	28,382	Hunt.....	50,317	49,713
Wharton.....	27,383	12,870	Delta.....	24,705	26,256
Total.....	371,349	174,174	Total.....	338,871	378,612
Decrease..... per cent.		53	Increase..... per cent.		11

The first section of the above table shows a comparison of the production in ten counties in Texas in 1899, when the weevil had scarcely reached them, and in 1902, when it had multiplied to such an extent as to be found in great numbers in practically all cotton fields. These two years were selected for comparison for the reason that they were practically identical in amount and distribution of rainfall and in other essential crop conditions. The second part of the table gives a comparison of the production during the same years in ten other leading counties situated so far north that the weevil had not affected them in either of the two years used for comparison. It will be noticed that while in the counties of the first series there had been a decrease in production of 53 per cent, in the counties of the second series there had been an increase of 11 per cent. There seems to be no reason why the cotton production of the counties of the first series would not have increased at about the same rate as was the case in those of the second series had it not been for the damage caused by the weevil. This makes it fair, it is believed, to conclude that the approximate damage caused by the insect was the sum of the decrease in one case and the increase in the other, or about 64 per cent.

There are two sources of possible error in these figures. One is in the likelihood of a change in acreage between 1899 and 1902 that may not have affected the two regions alike, and the other is in the probability that the two seasons were not exactly similar. In relation to the first point it must be stated that increases in acreage are generally the result of conditions of the markets that would affect the whole State alike, and that if there were any increase in these years it would probably have been very much alike in either case. As to the possibility of an appreciable difference in the seasons, it must be stated that the two regions are comparatively close together, and that a careful examination of the records shows that they were remarkably alike in all important respects. Nevertheless, it is the tendency of planters, as soon as the weevil becomes a serious menace, to devote more of their land to other crops. Accurate figures on this point are not obtainable, but on the whole an allowance of a reduction of this kind that would account for 10 per cent decrease in production would be ample. It therefore seems to the writer that a figure in the neighborhood of 50 per cent represents a very fair approximate estimate of the loss.

Upon the foregoing basis, assuming that there is a loss of about 50 per cent in newly invaded regions, but with an offset due to improved methods in older regions, it seems very conservative to state that, during the season of 1904, the weevil caused a reduction of at least 450,000 bales, representing a value, including that of the seed, of about \$22,000,000.

There are many interesting features connected with the relation between the damage of the weevil and the present very large cotton crop (estimated by the Bureau of Statistics of this Department, December 3, 1904, as 12,162,000 bales). The question has been raised as to why the weevil is a great menace in view of this large production and the fact that the pest has now invaded at least 32 per cent of the cotton acreage in this country. The following appear to be the principal reasons for the present large production:

(1) The high price of cotton just prior to the time of planting the crop of 1904 undoubtedly had the effect of increasing the acreage considerably.

(2) The boll weevil has not yet reached numbers in all its range sufficient to appreciably reduce the crop. The map on page 12 outlines the total area in which any weevils are known to occur. In perhaps 10 per cent of the territory thus considered infested only isolated colonies occur, and the general production has not yet been curtailed. In some of the northern counties of Texas the production could not have been reduced by the weevil, although the statistics show considerable variation between the crops produced for the past several years on account of changes in acreage and the ravages of other insects, like the bollworm.

(3) Throughout the portion of Texas where the bulk of the crop is produced—that is, north of about the latitude of Bremond—various conditions combined to cause an unusually small number of weevils to hibernate successfully during the winter of 1903–4. The principal factor in this situation was the very early date of the first killing frost, which was about thirty days prior to the average date for the past fifteen years. This early frost destroyed a great number of immature weevils in the squares and bolls which would otherwise have passed through the winter to damage the crop in spring.

(4) An important factor which has contributed to the production of a large crop in the region just mentioned has been a lessened degree of damage by the bollworm. It is estimated by Mr. A. L. Quaintance, who has been in charge of a special investigation of the bollworm, that the pest could not have caused more than half the damage in 1904 that was caused by it in 1903.

(5) The growing season was unusually favorable. The average condition of the growing crop in Texas, from May to September, inclusive, as published by the Bureau of Statistics of this Department, was 82 in 1904, as against 72.5 in 1903. The average condition for 1904 was, in fact, much higher than in even the season of the largest crop ever produced, namely, 1900, when the average condition reported for the months mentioned was 77.6.

(6) The season of 1904 was exceedingly favorable during the time of picking the crop, resulting in an unusually small loss of lint from rains.

(7) The large amount of work done by the Department of Agriculture and commercial bodies which imported many carloads of improved seed doubtless contributed to the large crop produced.

A general idea of the effect of the ravages of the boll weevil in reducing the crop in Texas may be obtained from the following table:

Comparison of cotton acreage and production in Texas and Louisiana, in equivalents of 500-pound bales.

Year.	Texas.		Louisiana.	
	Acreage.	Crop.	Acreage.	Crop.
	<i>Acres.</i>	<i>Bales.</i>	<i>Acres.</i>	<i>Bales.</i>
1899	6,642,309	2,609,018	1,179,156	700,352
1900	7,041,000	3,438,386	1,285,000	705,767
1901	7,745,100	2,502,166	1,400,650	840,476
1902	8,006,546	2,498,013	1,662,567	882,073
1903	8,129,300	2,471,081	1,709,200	824,965
1904	8,704,000	3,030,433	1,950,000	893,193

It will be seen that while the acreage in Texas and Louisiana has been increasing at about the same proportion, the crop in Texas has decreased annually for the past six years (with two exceptions—1900 and the present year), while the crop in Louisiana has increased annually (with one inconsiderable exception—in 1903). That the boll weevil is the cause that has prevented Texas from keeping pace with Louisiana will be admitted by all. The exceptional years, 1900 and 1904, in which the production in Texas did not decrease, were undoubtedly those in which the conditions for the cotton plant were unusually favorable. Moreover, it is to be noted that in the first of these two years the pest had not reached far into the most productive counties.

A VARIETY TEST.

In order to test the suitability of a number of varieties of cotton for planting in weevil-infested regions, during 1904 the Bureau of Entomology planted the seed of 20 of the more or less well-known varieties at Calvert, Tex. Each variety was represented by a plat 5 acres in extent. The soil was uniform throughout the acreage covered by this experiment. The test was a severe one on account of unusually unfavorable local conditions. The crop was made several weeks late by successive frosts early in the season. By a comparison with the results of the variety test conducted during the season of 1903, which

was noted in Farmers' Bulletin 189 of this Department, it will be seen that the general advantage of the early maturing varieties over the late maturing ones is again demonstrated. During that season the Herndon variety turned out to be the most prolific. This variety was not tested during the season of 1904, for the reason that it was impossible to procure seed. It was a local variety known in only one county in Mississippi, and seems to have died out on account of the general desire of planters for varieties which have large bolls.

In reality the superiority of the early maturing varieties would be more in evidence than the following grouping would indicate. In arranging the planting of varieties in the field the earlier ones were placed nearest the timber. It was designed to have the varieties graded from the vicinity of the timber according to their relative earliness. Consequently the King variety was nearest the timber, and the Russell most removed. As is usual in such cases, the weevils appeared in the cotton near the timber first. For two weeks before any of the pests had appeared in the middle of the field they were causing considerable damage in the plats nearest the timber.

It is not possible to give varieties of cotton a complete test during a single season. The only correct basis for an estimation of the value of different varieties in weevil-infested regions is a repetition of experiments during several seasons. As has repeatedly been found to be the case in the tests of varieties of cotton which have been conducted by southern experiment stations, the changing climatic conditions alter the relative standing of the varieties very materially. In some cases a variety found during one season to be at the head of the list in production may, during the following season, fall far below. Work that has been conducted elsewhere in Texas indicates some probable modifications of general conclusions that might be drawn from this test. For instance, the Rowden variety would probably rank considerably higher than was the case in these experiments. Nevertheless, it is believed that the test conducted by the Bureau of Entomology in Robertson County will furnish the basis for a general idea of the value of some of the principal known varieties.

The lint from the varieties was given commercial grading as specified in the accompanying table, by a special committee of members of the Galveston cotton exchange, appointed at the suggestion of the writer by the president of the exchange.

The name "Georgia Truitt" applies to the seed of the well-known Truitt variety from Georgia. The name "Texas Truitt" is used to differentiate the cotton grown from Truitt seed which had been planted in Texas for one year. The same distinction applies to the names "King" and "Texas King."

Comparison of cotton varieties.

Variety.	Yield per acre, seed cotton.	Percentage of lint.	Rank by yield.	Class.	Staple.
	<i>Pounds.</i>				
Territory	885.4	28.17	2	Barely low middling	Weak.
Georgia Truitt	719.0	27.76	5	Strict good ordinary	Fair.
Shine	670.4	32.07	6	Low middling	Do.
Dickson	436.2	28.91	14	Low middling to strict low mid- dling.	Poor.
Texas King	599.2	29.25	7	Strict low middling	Fair.
Meyers	483.8		12	Strict good ordinary	Do.
Van Nose	525.6		11	do	Do.
Texas Truitt	511.4	27.75	8	do	Poor.
King	863.4	31-32.53	3	Strict low middling	Do.
Native	427.2	33.28	16	do	Fair.
Russell	387.0		17	Good ordinary	Poor.
Tool's	944.8	30-34.43	1	do	Very poor.
Rowden	214.2		22	Low middling	Good.
Berry	338.8		19	Strict good ordinary	Very poor.
Parker	566.6	29.95	9	Low middling	Good.
Texas King	599.2	27.74	7	Strict good ordinary	Fair.
Mascott	534.4	33.52	10	Strict low middling	Do.
Otto	398.0	33.23	16	Good ordinary	Poor.
Hawkins	845.0	32.33	4	Good ordinary to strict good ordi- nary.	Do.
Culpepper	235.0		21	Strict good ordinary	Fair.
Eudaly	361.8		18	Good ordinary	Poor.
Native	428.6		15	do	Do.
Hetty	476.0	31.82	13	Low middling	Fair.
Welborn	323.2		20	Strict good ordinary	Do.

Arranged according to production, these varieties may be grouped in the following manner:

First group, yielding from 700 to 1,000 pounds of seed cotton per acre: Tool's, Territory, King, Hawkins, Georgia Truitt.

Second group, yielding from 500 to 700 pounds of seed cotton per acre: Shine, Texas King, Texas Truitt, Parker, Mascott.

Third group, yielding from 400 to 500 pounds of seed cotton per acre: Van Nose, Meyers, Hetty, Dickson, Native.

Fourth group, yielding from 200 to 400 pounds of seed cotton per acre: Russell, Eudaly, Berry, Welborn, Culpepper, Rowden.

Arranged according to class, the above-mentioned varieties may be ranked in the following manner:

Fair: Texas King, King, Native (No. 10), Mascott.

Middling Fair: Dickson.

Good Middling: Shine, Rowden, Parker, Hetty.

Middling: Georgia Truitt, Texas Truitt, Meyers, Van Nose, Berry, Texas King, Culpepper, Welborn.

Low Middling: Territory.

Good Ordinary: Hawkins.

Ordinary: Russell, Tool's, Otto, Eudaly, Native (No. 23).

The two "natives" represented two different lots of seed.

Arranged according to staple, the varieties stand as follows:

Good: Rowden, Parker.

Fair: Georgia Truitt, Shine, Texas King, Meyers, Van Nose, Native, Mascott, Culpepper, Hetty, Welborn.

Weak: Territory.

Poor: Dickson, Texas Truitt, King, Russell, Otto, Hawkins, Eudaly, Native.

Very Poor: Tool's, Berry.

Arranged according to the average rank by class and staple, the varieties could be grouped in the following manner:

First Group: Texas King, Native (No. 10), Mascott.

Second Group: Rowden, Parker.

Third Group: Shine, King, Hetty.

Fourth Group: Georgia Truitt, Dickson, Meyers, Van Nose, Texas King, Culpepper, Welborn.

Fifth Group: Texas Truitt.

Sixth Group: Territory.

Seventh Group: Berry.

Eighth Group: Hawkins.

Ninth Group: Russell, Otto, Eudaly, Native.

Tenth Group: Tool's.

CONCLUSIONS REGARDING THE USE OF FERTILIZERS.

The Bureau of Entomology has not conducted any special tests of fertilizers. However, in the prosecution of a great number of the general experiments, it has been necessary to make use of commercial fertilizers. In view of the lack of exact knowledge regarding the proper use of fertilizers in Texas, due to conditions which are in many respects dissimilar to those in regions where experiments with fertilizers have been conducted, it is considered advisable to present some of the incidental results along this line.

The uncertainty connected with field experiments during a single season is nowhere more marked than in the use of fertilizers. The benefits derived from the use of fertilizers depend upon soil and climatic conditions, as well as upon the preparation the ground is given. The climatic conditions may cause some fertilizers to be available during one season, while during another season no results might be evident from their use. During the season of 1904, the results of the use of fertilizers were confusing. However, some of the results that are doubtless of more or less general application are referred to in the following paragraphs. That these conclusions are approximately correct is shown by the fact that they agree in a general way with the results of the various State experiment stations which have conducted fertilizer experiments in the South.

On sandy post-oak land in Robertson County, in one case the application of a fertilizer consisting of 200 pounds of cotton-seed meal and

100 pounds of acid phosphate per acre produced a yield of 900 pounds of seed cotton, which was 50 per cent more than the yield of the same variety of cotton in an unfertilized part of the same field. In another case, on similar soil in Robertson County, 200 pounds of acid phosphate (14 per cent available phosphoric acid) caused an increase of 163 pounds of seed cotton per acre. On river-bottom soil in Robertson County an application of 140 pounds of cotton-seed meal with 140 pounds of acid phosphate per acre caused an increase in yield of 180 pounds of seed cotton per acre. In this locality, as well as on alluvial soil in Wharton County, the application of 200 pounds per acre of acid phosphate having 14 per cent of available phosphoric acid did not increase the yield appreciably.

The most striking results from the use of fertilizers were obtained in the case of the work conducted in Washington County on heavy, sandy river-bottom soil, which had been planted in cotton or corn for at least fifteen years. The application of 200 pounds of acid phosphate increased the yield about 20 per cent. The application of 300 pounds of this fertilizer increased the yield in the neighborhood of 50 per cent, not only in the case of improved varieties, but also in the case of native cotton. The largest yields obtained anywhere during the season by the Bureau of Entomology were in this location. One field of native cotton, fertilized with 300 pounds of acid phosphate, yielded at the rate of 1,712 pounds of seed cotton per acre. Two other plats fertilized at the same rate yielded 1,632 and 1,437 pounds of seed cotton per acre, respectively. Some of the plats fertilized with the amount of acid phosphate that has been mentioned did not yield nearly as high; nevertheless the average on the fertilized plats reached in the neighborhood of 1,000 pounds of seed cotton per acre as against an average yield of 527 pounds of seed cotton per acre in the case of unfertilized plats.

Upon black prairie soil in Karnes County, 200 pounds of acid phosphate per acre on the average, with several different varieties of cotton, increased the yield considerably. On 30 acres of early maturing varieties and native cotton, the amount mentioned resulted in a net gain of \$5.65 per acre. Heavier applications of acid phosphate, at 400 and 500 pounds per acre, did not result in a net gain greater than that mentioned in the application of 200 pounds. On the same plantation an application of 300 pounds of a complete fertilizer, analyzing 8 per cent phosphoric acid, 2 per cent nitrogen, and 2 per cent potash, caused an increase in the yield per acre of 253 pounds of seed cotton, resulting in a net gain per acre of \$5.07.

A careful consideration of the subject of the fertilization of cotton in Texas, by Prof. R. L. Bennett, will be found in Bulletin No. 75, Texas Agricultural Experiment Station.

RELATION BETWEEN SEPPA COTTON AND WEEVIL DAMAGE.

The winter of 1903-4 was unusually mild in Texas. The consequence was that the region in which volunteer cotton occurred extended much farther north than normally. Some volunteer cotton occurs in Texas every year, but its occurrence north of about the latitude of Victoria is unusual. During the year 1903-4 much volunteer or seppa cotton was found as far north as Milam County. A line through the middle of Milam, Williamson, Travis, and Hays counties would indicate the northward limit of the territory in which seppa cotton occurred during the season. In many fields in Karnes, Wilson, and other counties practically every root of the preceding year overwintered. It must be evident to any observer that this condition must conduce to the most successful hibernation of the weevils. They are provided with food practically throughout the winter, and in the spring there is an abundance of green sprouts long before the planted cotton has come up. The consequence is that there is a much smaller mortality rate during the winter in this region than elsewhere. The very great damage which was done in 1904, in the counties of southwest Texas last mentioned, was due to the occurrence of this seppa cotton. By the latter part of June it was found that in some localities practically all the fruit on these plants had become infested. This resulted in at least one additional brood of weevils to prey upon the planted cotton.

The Bureau of Entomology has repeatedly pointed out that the presence of volunteer cotton is the greatest menace to the crop that exists in southern Texas. The encouragement of such plants is undoubtedly the worst possible practice in weevil-infested regions. The disastrous experience of many counties in the southern portion of the State during the past season has abundantly demonstrated the force of the warnings that have been issued from time to time. The staple produced upon seppa plants is exceedingly short and weak, and is not desired by the trade. Before the advent of the weevil, the only reason for encouraging such growth was to procure the first bale. Now, on account of the fact that the presence of such plants intensifies the seriousness of the weevil problem, any attempt to produce cotton from the stalks of the preceding year should by all means be discouraged. The proper procedure would be to destroy all the plants in the field early in the fall, as suggested in the list of recommendations.

EXPERIMENT IN DEFERRED PLANTING.

In Texas some little attention has been attracted to the proposal of eradicating the boll weevil by deferring the time of planting until very

late in the season. The idea has been that by following with such a practice after the early destruction of the plants in the fall the hibernating period of the weevils could be so lengthened that all would perish. From superficial considerations it would seem that late planting instead of early planting would be the proper way to avoid damage by the pest. In order to determine this point definitely, the Bureau of Entomology conducted a special experiment at Victoria, Tex., during the season of 1904. A field was selected which was isolated from all other cotton fields by a dense growth of huisache, the nearest cotton being nearly a mile away. The field under consideration was 20 acres in extent and had been planted in cotton during the season of 1903, when the weevils became very numerous. The stalks were removed in the latter part of November. During the spring sprouts sprang from a number of the roots remaining in the ground, but these were destroyed with hoes from time to time. After this preliminary treatment the field was planted in King cotton on May 23. The climatic conditions in general were favorable, resulting in a rapid growth. On July 15 an examination showed that the weevils were generally distributed throughout the field, although the damage at this time was not great. On August 3, however, it was found that 90 per cent of all the squares in various parts of the field were infested. By August 31 no blooms whatever were to be seen. A small number of bolls were in evidence, but very few of them were open. This field yielded altogether only 3,240 pounds of seed cotton, less than one-tenth of a bale of lint per acre.

As a check upon the foregoing experiment another isolated field was selected which had been in cotton continuously for seven years. In this case 5 acres were planted with seed of the Parker variety of cotton during the last week in February. It was found that weevils made their appearance in this field in great numbers at approximately the same time as they appeared in the field planted very late. The total yield on the 5 acres planted in February was 6,999 pounds of seed cotton, or 1,398 pounds per acre.

As against a yield of about one-tenth of a bale per acre in the late-planted field we have, in the early-planted one, a yield of nearly a full commercial bale per acre.

The evident conclusion from this experiment is that even under the most favorable circumstances late planting can not be relied upon to save the crop. Aside from the general difficulties in late planting and the likelihood that the crop will be damaged by the other insect pests, it seems that a number of weevils sufficient to thoroughly infest the field in a short time succeed in passing the prolonged period of hibernation. The late-planted cotton grew well, and the only important factor in reducing the yield was the boll weevil.

CONTROLLING THE BOLL WEEVIL IN COTTON SEED AND AT GINNERIES.

The possibility of controlling the boll weevil in cotton seed and at ginneries received special attention during the season of 1904.

The Bureau of Entomology employed a ginning expert, and many experiments were conducted with gins in actual operation. The results of this work have received full consideration in Farmers' Bulletin No. 209 of this Department, which may be had upon application. In this connection it is sufficient to state that the facility with which weevils may be transported from infested to uninfested localities in cotton seed has been fully demonstrated, and the exact points where danger may be avoided in the process of ginning have been determined. The two means of preventing danger from the transportation of weevils in cotton seed are (1) the fumigation of the seed, and (2) the application in ginneries of the devices that will more or less effectually remove the weevils from the seed. For detailed information the reader is referred to Farmers' Bulletin No. 209.

SUPPOSED IMMUNITY OF MEXICAN COTTONS.

Reported immunity from boll weevil attack of certain so-called Mexican tree cottons, with their possible value in the cotton-growing States, was investigated by an agent of the Bureau of Entomology during the month of September, 1904. As these cotton trees were said by their promoters to produce their first lint the second season from the date of planting, it was evident that if they were found to be affected by frosts their immunity from the boll weevil, if such a condition existed, could be of no practical value in this country. Persistent reports,^a however, concerning the ability of the tree cotton to withstand frosts and its immunity against the attacks of the boll weevil, made it desirable for the Bureau to obtain reliable information at first hand.

Tree cotton grown from seed received from the locality in Mexico and from the cotton planter from whom practically all of the above-mentioned reports emanated, was observed by the representative of

^aThe following quotation from a daily newspaper illustrates the character of the reports referred to: "The plant begins bearing when five years old and continues to be productive for half a century or more. In some instances a single tree is known to produce as much as 59 pounds of cotton in one season, the fiber being very similar to that of the cotton plant and adaptable to the same uses. It is immune against the boll weevil and all other insect pests, and, under proper conditions, the growing of it may be immensely profitable." The Mexican cotton planter, to whose cotton trees the above and like current reports referred, in a letter to a gentleman in Mexico City, a copy of which the writer has seen, states that the "tree cotton" begins to produce staple in paying quantities at the age of *two years*.

the Bureau growing under various conditions of soil, climate, and elevation. The most significant conditions were found at San Bartolo, State of San Luis Potosi, Mexico, at the hacienda of Espinosa y Cuevas Hnos., this being the only locality where tree cotton was found growing for which accurate temperature records were available. A comparison of these records with the United States Weather Bureau records at Brownsville, Tex.—which point represents the mildest climate of the cotton belt of the United States—shows that both the minimum and daily mean temperatures of the two places are very nearly alike during the winter months. At the Mexican hacienda referred to, the owners state that the tree cotton was injured by the light frosts during the winter of 1902-3 to the same extent as was the American upland cotton growing there. An examination of many squares of the tree cotton plants showed that fully two-thirds of them were infested by the boll weevil. At Cuernavaca, State of Morelos, Mexico, the squares of a variety of cotton known among the natives as Algodon Arbol (cotton tree) were found to be badly infested by the boll weevil. At all places where Mexican tree cotton was found entirely free from the boll weevil it was undoubtedly due to the nonexistence of the insect in that section.

The observations mentioned in the foregoing paragraphs lead to the conclusion that there is no variety of cotton in Mexico which is immune to the boll weevil. This conclusion is borne out by experiments conducted at Victoria, Tex., with cotton plants grown from the seed of a large number of varieties procured in Mexico and Cuba.

FUTILE METHODS SUGGESTED FOR CONTROL.

In some quarters of Texas and Louisiana there is still considerable misunderstanding about the habits of the boll weevil, and many fallacious suggestions are proposed from time to time. The supposition exists in many quarters that the boll weevil is attracted to lights. A number of machines based upon this idea have been constructed. The possibility of attracting the boll weevil to lights was one of the first matters relating to the pest to be investigated by entomologists. During September, 1897, Mr. J. D. Mitchell, of Victoria, Tex., a naturalist and cotton planter, set out trap-lanterns in cotton fields in Victoria County for one night. The insects captured were sent to the Bureau of Entomology for examination. In all 24,492 specimens were taken, representing approximately 328 species. Divided according to habit, whether injurious or beneficial, the result was: Injurious species 13,113 specimens, beneficial species 8,262 specimens, of a neutral character 3,117. The interesting point in connection with this experiment was the fact that not a single specimen of the boll weevil was found, although the lights were placed in the

midst of a field where the insects were very abundant. Since that time other investigators have looked into the matter carefully. Lights have been kept burning in cotton fields. In no case has a single specimen of the boll weevil been captured in this manner, although thousands of species of insects have been taken. The public misapprehension about the possibility of capturing the boll weevil with lights is due to the fact that a somewhat similar insect, *Balaninus victoriensis*, and other acorn weevils, differ from the boll weevil in that they fly at night and lights exert a strong attraction for them. During certain seasons the acorn weevils are exceedingly common in Texas, and great numbers of them fly to the electric lights.

The old idea, the fallacy of which has been explained repeatedly by entomologists for the past fifty years, that sulphur can be forced into the system of plants to make them immune to insect attack, sometimes creeps out with reference to the boll weevil. The method is entirely useless. Sulphur is not soluble either in water or acids. It is consequently impossible for it to be taken up by the plants. In chemical combinations, in which forms only could it be assimilated by the plants, there is nothing to indicate that it would have special insecticidal properties. The usual form in which the use of sulphur has been recommended in Texas is that the seed should be soaked before planting in water containing it. Money used in this manner is entirely wasted.

Undoubtedly the most important fallacious remedy that has ever been proposed for the boll weevil is Paris green, which received a great deal of attention during the season of 1904. The urgent demand for a specific remedy on the part of the planters was evidenced by the extensive use of this substance. At least 25 carloads were used in Texas during three months. A portion of the great attention that Paris green attracted was due to the fact that early in the season a certain number of weevils may be killed by it. The number destroyed in this manner early in the spring really means nothing whatever to the crop later, when the plants have put on squares and the poison no longer reaches the pest. It has been demonstrated that the great majority of the weevils do not emerge from hibernating quarters until the plants begin to put on squares. Those that emerge in this manner can not be affected by any amount of Paris green that might be applied. The Bureau of Entomology has had fields dusted repeatedly throughout the season, but without benefit. The results of many experiments with Paris green will be found in Farmers' Bulletin No. 211 of this Department.

Among the futile means of controlling the boll weevil the large number of machines that have come to public attention from time to time must be included. There is some possibility that ultimately an

effective machine may be perfected. Careful tests which have been made with all those proposed up to the present time, however, do not show any decided hope in this direction. These machines have been designed to poison the insects, to jar them and the infested squares from the plants, to pick the fallen squares from the ground, to kill by fumigation, and to burn all infested material on the ground. It is estimated that over one thousand machines of a certain class, designed to jar the weevils and infested squares from the plants, were sold in Texas during the season of 1904. The testimony of all users of these machines is now to the effect that they are entirely useless as far as the increasing of the crop is concerned. As each one of these machines was sold for \$40, the loss to the people of the State can be seen to be very great. By such means it is, of course, possible to capture a certain number of weevils in the field. The great number remaining and their rapid rate of multiplication render this small number entirely inconsequential.

The Bureau of Entomology follows the general policy of investigating all machines that are proposed; but no machine has yet been found sufficiently effective to be recommended. In fact, there seems at present to be little probability that such a machine will ever be perfected.

A great number of poisons to be used as sprays and in other forms have been proposed. It is usually supposed that some exceedingly toxic substance has been discovered which, in a very diluted quantity, will kill the insects with which it comes in contact. Other applications are designed to repel the insects from the plant by some supposedly offensive property. It is almost needless to state that all these proposed remedies are entirely without value.

QUARANTINES AGAINST THE BOLL WEEVIL.

In the attempt to prevent the introduction of the boll weevil several State legislatures have enacted laws which either in themselves restrict the shipment of commodities believed to be likely to convey the pest, or authorize State crop pest commissions or State entomologists to promulgate and enforce rules and regulations to this end. Unfortunately there is very little uniformity in State regulations now in force. Some States have quarantined articles that are admitted unrestrictedly by others, and, moreover, from time to time numerous modifications of the regulations based upon these laws have been made. This has resulted in endless confusion to shippers and transportation companies. The natural commercial course of at least 5,000 carloads of Texas farm products was either interfered with decidedly or prevented entirely by the operation of these laws during the season of 1904. In view of this situation the Department of Agriculture suggests the following plan for a State law, providing for quarantines,

as well as for eradicating possible isolated colonies that may be discovered, and also providing a means of enforcing remedial work at the earliest possible moment. It would be decidedly to the interest of all the States concerned to bring their regulations into conformity with these suggestions as soon as possible. The Department's suggestions are based upon a careful study of the habits of the boll weevil during several seasons, as well as upon knowledge gained from a large amount of inspection work which devolved upon the Bureau of Entomology in consequence of the State laws now in effect. It is believed that they will furnish sufficient protection and at the same time not interfere unnecessarily with shipping. They are based upon the suggestions toward a uniform quarantine system adopted by representatives of practically all the principal cotton-producing States who met at Jackson, Miss., August 2, 1904, with such modifications as seem advisable as a result of the subsequent study by the Bureau of Entomology of the means by which the pest is disseminated.

SUGGESTIONS FOR A UNIFORM STATE BOLL-WEEVIL LAW.

(1) Plenary authority should be delegated to a board, the executive officer of which should be an entomologist, to take whatever steps may be found necessary for eradicating or controlling the boll weevil.

(2) A prohibition against bringing into the State, or having in possession, live boll weevils should be included, with a suitable penalty affixed.

(3) Definite authority should be given the officer or officers in charge of the boll-weevil quarantine matters to establish from time to time such rules and regulations as may be necessary.

It is considered that the foregoing provisions are sufficient for the law itself. Many other matters growing out of quarantine work deal with changing conditions and consequently should be covered by rules and regulations which may easily be changed as the occasion demands. These regulations should include an absolute quarantine against cotton seed, seed-cotton, cotton-seed hulls, baled cotton (whether compressed or flat), and corn in the shuck from infested territory. The basis for this recommendation is that the weevil has been found to be transported easily in cotton seed and other cotton products. As will be specified later, there is, under some conditions, considerable danger in the shipment of baled cotton. Corn in the shuck is included for the reason that it often furnishes hibernating quarters for weevils. This absolute quarantine should be modified to the extent of allowing the shipment of any of the foregoing articles after they have been properly fumigated under the direction of the Bureau of Entomology. The quarantine should be directed against all territory infested or

which may become infested, rather than against a list of certain counties.

A long list of other farm products have been quarantined by various States. This list includes hay, wheat, oats, cowpeas, fruit, vegetables, rice, and rice products. The Department of Agriculture does not consider that there is any appreciable danger in the shipment of these commodities at any time of the year. Numerous examinations that have been made have failed to reveal the presence of weevils, and since from the previous extensive shipping from infested portions of Texas to all parts of the South no infestation has been found to have resulted, it can not be considered necessary to extend quarantines to cover these products. It is true that there may be danger in such shipments under certain circumstances, nevertheless there seems to be no more danger in connection with these articles than there is in the shipment of general merchandise or in the interstate movement of empty box cars. The boll weevil does not feed upon any of these articles. Specimens may possibly occur among them, but their presence seems no more likely in such situations than in any articles of commerce which may be stored in the neighborhood of cotton fields, or which may pass through regions where cotton fields from which weevils might fly at any time are situated in the vicinity of the railroad. The work which has been conducted by the Bureau of Entomology, in cooperation with the Louisiana crop pest commission, has given many opportunities for determining whether certain farm products are likely to convey the boll weevil. Every colony found in Louisiana during 1904 has been studied carefully. In no case has there been any suspicion that the pest was conveyed to new regions in any commodities except those against which a provisional absolute quarantine is suggested.

It does not seem feasible to allow the shipment of certain commodities during some months and exclude them during others. Some of the rules and regulations now in effect quarantine hay, for instance, except during July, August, and September. The supposition in these cases has been that during those months the weevils will be found in the cotton fields, while during the remainder of the year they may have taken flight to hibernation quarters, thus infesting a large number of commodities that would be uninfested during the other months. As a matter of fact, it has been found that there is usually an extensive flight of weevils as early as the middle of August. Shipment of hay or moss would therefore be practically as dangerous during summer as at any other time of the year. However, it is not considered that such danger at any time is great enough to warrant the inconvenience that is caused shipping interests by the enforcement of quarantines.

Some of the States have also quarantined bedding used by common carriers with shipments of live stock. The Department does not

consider that there would be any danger whatever in the use of hay or straw for this purpose.

Household goods have caused great confusion in quarantine regulations. The origin of the quarantine of household goods on the part of several States was the knowledge of very extensive emigration of negro tenants from infested portions of Texas to all parts of the South. It is the custom of such emigrants to carry along small quantities of special cotton seed, as well as to use cotton seed or seed cotton in packing furniture and other articles. As these practices involve the possible shipment of some of the commodities which should be quarantined, it is suggested that the shipment of household goods should be prohibited in all cases where the consignments are not accompanied by affidavits attached to the waybill stating that no cotton seed or other articles named as dangerous in a preceding paragraph are included.

The quarantine officer should have ample authority to modify, in special cases, whatever rules and regulations are promulgated. Such special cases might occur, for instance, in the treatment of baled cotton. There is no doubt that a general quarantine should be enforced against this product. There is considerable danger in shipping baled cotton to mills where cotton fields are adjacent, since the bagging around bales that have been stored near gins in infested territory might easily carry weevils. Nevertheless, a general quarantine should not be made to apply to shipments of baled cotton to mills in the cities, or to shipments to ports for direct export. Many similar cases where special action may be necessary will arise from time to time. The best method for providing for such cases is to grant considerable breadth of authority to the quarantine officer.

PRESENT QUARANTINES OF THE SEVERAL STATES.

Quarantines designed to prevent the importation of the boll weevil are now in force in the following six States: Alabama, Georgia, Louisiana, Mississippi, North Carolina, South Carolina. They are directed against all counties in Texas and parishes in Louisiana that are indicated as infested on the map on page 12, as well as against such counties or parishes as may become infested in the future. The following pages give the substance of the present restrictions. For further particulars the quarantine officers of the several States should be addressed directly.

Alabama.—The following act of the Alabama legislature was approved October 6, 1903:

AN ACT To prevent and prohibit the importation of seed from cotton affected with the Texas boll weevil.

SECTION 1. *Be it enacted by the legislature of Alabama,* That no person shall import or bring into the State of Alabama any seed from any cotton affected with what is

known as the Texas boll weevil, nor the seed from any cotton from any place where the cotton has been affected with said boll weevil.

SEC. 2. Any person who violates the provisions of section 1 of this act shall be guilty of a misdemeanor, and on conviction shall be fined not less than ten dollars (\$10) and not more than five hundred dollars (\$500).

(H. 877, No. 559, approved October 6, 1903.)

Recently (January 25, 1905) the State board of horticulture of Alabama has adopted quarantine regulations against the boll weevil, based upon the recommendation for a uniform system of quarantine rules made by the association of official entomologists of the cotton belt, an association consisting of State entomologists, together with agents of the Bureau of Entomology of this Department. By these regulations an absolute quarantine is established at all seasons of the year against cotton seed, seed cotton, hulls, cotton-seed and seed-cotton sacks which have been used, cotton picker's sacks, corn in the shuck, unsacked corn, unsacked oats, unsacked wheat, and unsacked cowpeas. During the months of July, August, and September there are no restrictions against the importation of hay, straw, sacked wheat, sacked oats, sacked shelled corn, sacked cowpeas, and unbaled Spanish moss, but during the remaining nine months of the year the importation into the State of any of these articles from quarantined counties or parishes is prohibited. Through shipments of quarantined articles may be made in cars which must be tightly closed, and no unloading is allowed during transit through the State. Household goods to be shipped from the infested territory into the State of Alabama must be accompanied by an affidavit attached to the way bill stating that no quarantined articles are contained in the shipment as packing or otherwise. Baled cotton can be shipped into the State only in tightly closed cars.

Particulars regarding the Alabama quarantine regulations may be obtained by addressing Prof. J. F. Duggar, Experiment Station, Auburn, Ala.

Georgia.—Previous to August 15, 1904, the Georgia State board of entomology had authority, by virtue of the legislative act which created it, to enact such regulations as it deemed necessary to prevent the introduction or dissemination of injurious crop pests or diseases. On August 28, 1903, this board adopted a regulation prohibiting the introduction of cotton seed from Texas except under a certificate from an authorized State or Government entomologist stating that the seed had been fumigated in such manner as to kill any stage of boll weevils which might be contained therein. On August 15, 1904, an act of the general assembly of the State of Georgia was approved whereby cotton seed, seed cotton, cotton-seed hulls, or cotton lint in bales or loose, oats, hay, fodder, husks, straw, forage of any kind, corn in the husk,

or all material packed in anything originating on a farm or plantation, is prohibited from being brought into the State except when there is attached thereto a certificate signed by an authorized State or Government entomologist to the effect that said material was grown in and was shipped from a point where, by actual inspection, the Mexican cotton boll weevil was not found to exist.

Mr. R. I. Smith, Capitol, Atlanta, is the present quarantine official in Georgia.

Louisiana.—A special session of the State legislature enacted a law approved December 15, 1903, creating a Louisiana crop pest commission, which was authorized to promulgate and enforce such rules and regulations as seemed necessary in order to prevent the further spread or introduction into the State of the Mexican cotton boll weevil. The original rules and regulations of this commission were adopted on February 5, 1904, and since then have been amended in many particulars. At first prohibiting the importation of all farm products from practically all cotton-producing counties in Texas, they were afterwards modified, at the suggestion of and by arrangement with the Bureau of Entomology, in such a manner that all farm products except cotton seed, seed cotton, hulls, cotton-seed and seed-cotton sacks, hay, and straw were accepted for importation from Texas into Louisiana on the certificate of the Entomologist of the United States Department of Agriculture or his duly accredited representative. Corn, wheat, oats, and other grains, and cowpeas, by this arrangement, were to be certified to only during the months of July, August, and September. On December 14, 1904, the crop pest commission raised all quarantine restrictions on the last-mentioned commodities. Cotton seed, seed cotton, hulls, cotton-seed and seed-cotton sacks, hay, and straw in any form, whether as a packing for household goods, stuffing for mattresses, pillows, and cushions, or feed for stock, are absolutely prohibited from being shipped into Louisiana from 131 listed counties of Texas considered to be infested, as well as all others which may become infested with the cotton boll weevil, or from being shipped from an infested parish in Louisiana into an uninfested parish. Shipments through the State of quarantined articles must be handled in original tightly closed cars without unloading at any point within the State.

The present regulations prohibit the importation of household goods from infested localities when any of the above-mentioned quarantined articles are used as packing or in any other way. Shipments of mattresses, pillows, and cushions, filled with cotton, hay, straw, shucks, or other quarantined articles, are prohibited. Shippers are required to execute affidavits to the effect that mattresses, etc., have been filled with the substance contained for at least eighteen months before

shipment, otherwise such articles must be emptied. The affidavit is to accompany the way bill.

Mr. Wilmon Newell, Shreveport, La., is the quarantine officer of this State.

Mississippi.—An act of the State legislature entitled "A boll weevil quarantine act," approved March 18, 1904, empowers the State entomologist to prevent in every possible and practical way the introduction of the Mexican cotton boll weevil into that State by adopting and enforcing rules and regulations governing the transportation of farm products. A quarantine was instituted against 131 Texas counties and one Louisiana parish, as well as all other communities and parishes in which the boll weevil might be found to exist. The quarantined articles included cotton seed, cotton-seed hulls, cotton-seed meal, sacks used to hold these materials, hay, oats, straw, and corn. Nursery stock, fruit, and garden truck were accepted under these rules only when accompanied by a certificate of inspection by the Entomologist of the United States Department of Agriculture. All farm products passing through the State of Mississippi were required to be in tightly closed cars and not opened, unloaded, or sidetracked for more than twelve hours during transit across the State. These rules were amended to permit, during the summer months, the unrestricted shipment of oats into and through the State. On September 1, 1904, the rules and regulations referred to above were rescinded in toto, and a new set of rules went into effect, based on the recommendations for a uniform system of quarantine rules by the association of official entomologists of the cotton belt. These rules and regulations specify the same quarantined territory as did those for which they were substituted. An absolute quarantine is established against cotton seed, seed cotton, hulls, seed-cotton and cotton-seed sacks (which have been used), cotton-pickers' sacks, corn in the shuck, unsacked corn, unsacked oats, unsacked wheat, and unsacked cowpeas from the quarantined territory. During the months of July, August, and September there are no restrictions against the importation of hay, straw, sacked wheat, sacked oats, sacked shelled corn, sacked cowpeas, unbaled or baled Spanish moss, but during the remaining nine months of the year all of these articles from quarantined counties and parishes are prohibited from entering the State of Mississippi. Through shipments of quarantined articles must be in tightly closed cars, which must not be unloaded while in transit through the State. Household goods to be shipped from the infested territory into the State of Mississippi must be accompanied by an affidavit to the effect that no quarantined articles are contained as packing or otherwise in the shipment. Baled cotton can be shipped into the State only in tightly closed cars.

Prof. G. W. Herrick, Agricultural College, Miss., is the quarantine officer of this State.

North Carolina.—By virtue of authority from the State legislature, to prevent the importation of crop pests, the North Carolina crop pest commission early in 1904 adopted rules establishing a quarantine against all localities where the Mexican cotton boll weevil is known to exist. The quarantine was absolute, and applied to cotton, cotton seed, cotton-seed meal, cotton-seed hulls, hay, oats, corn, rice, straw, rice chaff, and other grain or material likely to harbor any stage of the boll weevil. On August 15, 1904, new quarantine regulations were adopted and substituted for the previous ones, conforming very nearly with the recommendations of the association of official entomologists of the cotton belt, and also with the Alabama and Mississippi rules, which have been described in previous paragraphs. The North Carolina quarantine regulations now in force differ from those of the States of Alabama and Mississippi only in the following particulars: Cotton and cotton-seed meal are included among the articles against which the quarantine is absolute at all times. The restrictions concerning Spanish moss in the North Carolina regulations specify only unbaled moss, as do those of Alabama.

Prof. Franklin Sherman, jr., Raleigh, N. C., is the quarantine officer in this State.

Oklahoma.—The Oklahoma legislature is now considering a boll weevil quarantine act. At the time of writing, however, no definite action has been taken.

South Carolina.—In South Carolina, as in Alabama and Georgia, the quarantine regulations are entirely embodied in the laws of the State and consequently not as readily modified to conform with the changed conditions and a better understanding of the methods of dissemination of the boll weevil, as is the case when authority to promulgate rules and regulations is invested in a commission or in the State entomologist. The law established to guard against the introduction of the Mexican boll weevil into the State of South Carolina was approved on February 25, 1904. The commodities quarantined against were cotton seed, oats, and prairie hay, shipped directly or indirectly from infested points in the State of Texas.

Prof. C. E. Chambliss, Clemson College, South Carolina, can furnish information concerning the interpretation of this law.

U. S. DEPARTMENT OF AGRICULTURE.

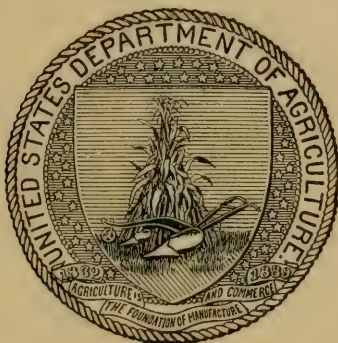
FARMERS' BULLETIN No. 223.

MISCELLANEOUS COTTON INSECTS IN TEXAS.

BY

E. DWIGHT SANDERSON,

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Department, A. and M. College of Texas.*



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1905.

LETTER OF TRANSMITTAL

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ENTOMOLOGY,

Washington, D. C., April 18, 1905.

SIR: I have the honor to transmit herewith the manuscript of a Report on Miscellaneous Cotton Insects in Texas, prepared by Prof. E. Dwight Sanderson, formerly State Entomologist of Texas.

This report is the result of a year's work on the minor insect enemies of the cotton plant, undertaken by Professor Sanderson and his assistants in order to supplement the work which has been done by the field agents of this Bureau, on the more important injuries by the cotton boll weevil and bollworm. It is written in popular form, and I recommend its publication as a Farmers' Bulletin.

Mr. Sanderson desires to acknowledge the valuable assistance given to him in the conduct of these investigations by Mr. A. C. Lewis, who was in charge of the laboratory at the demonstration farm of Mr. E. H. R. Green, at Terrell, Tex., and to Mr. C. E. Sanborn, who had charge of the laboratory work at College Station. A great part of the life histories of the insects discussed in the report is the result of the work of these gentlemen.

Very respectfully,

L. O. HOWARD,

Entomologist and Chief of Bureau.

Hon. JAMES WILSON,

Secretary of Agriculture.

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MISCELLANEOUS COTTON INSECTS IN TEXAS.

INSECTS WHICH AFFECT THE YOUNG PLANTS.

Prior to the advent of the Mexican cotton boll weevil (*Anthonomus grandis* Boh.) the retardation of the cotton crop on account of replanting, necessitated by the depredations of insect pests on the young plants, was of little importance. But since it is absolutely essential to mature an early crop of cotton if injury by the boll weevil is to be escaped, the matter of the injury to the young plants by other insects becomes a matter of much importance.

CUTWORMS.

As soon as the young plants have started to grow, and often after they have been chopped, many of them are destroyed by cutworms, which cut off the stems and often make replanting necessary over considerable areas.

Life history.—The complete life history of the species concerned is not known, but the winter is passed in the larval condition in all stages of growth, and in the southern part of the State more or less damage is done to gardens throughout the winter in open seasons. Early garden crops are injured worst in March, the injury often commencing by the middle of February and continuing until the middle of April or first of May. When full grown the cutworms form oval cells in the soil and transform into pupæ, the adult moths emerging three or four weeks later. The species most commonly found on cotton in 1904 were the black cutworm (*Agrotis ypsilon* Rott.), the moths and larvæ of which are shown in figure 1, and the shagreened cutworm (*Feltia malefida* Guen.). Injury to cotton by cutworms was not as serious in 1904 as often occurs, and it is probable that several species other than those mentioned above were concerned. The moths appear from the

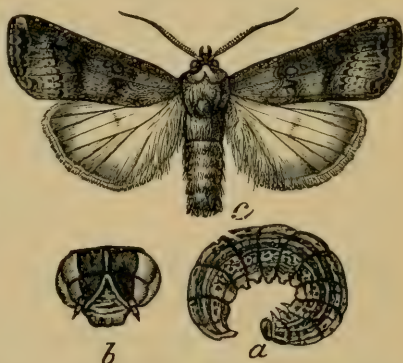


FIG. 1.—*Agrotis ypsilon*, one of the tobacco cutworms: a, larva; b, head of same; c, adult—natural size (after Riley & Howard).

middle of May to the middle of July. Both larvæ and moths are nocturnal insects, the larvæ feeding and the moths flying only at night. Planters report that cutworms are more abundant in seasons following a fall in which there have been abundant rains, making grass and weeds plentiful, and that these insects are more injurious at the sides of the fields, where, of course, vegetation was probably abundant the fall previous.

Remedies.—From the habits above outlined it may be seen that much can be done to control these pests by thorough cultivation of the land during late fall, winter, and early spring. When the land is thoroughly plowed many of the cutworms are exposed to abnormal weather and succumb, many are crushed, and still others are eaten by birds or insects. Then, too, when the land is fallow in early spring there is nothing upon which the cutworms can feed and these starve before the cotton is planted. If found abundant in spring, however, they may be best combated by the use of poisoned traps. The mash described on page 10 for grasshoppers will be found very satisfactory, but is rather expensive for large areas. In its place, grass, clover, or other rank vegetation poisoned with Paris green will be found effective if scattered over the field in small bunches a few days before the plants appear. Bunches of the grass may be dipped in Paris green, 1 pound to a barrel of water, or a small area of grass or clover may be thoroughly sprayed and then cut and distributed from a wagon. These traps will be most successful where the land has been plowed some time before, for cutworms will often feed for several days where there is much vegetation which has been but recently turned under.

PLANT-LICE.

With the formation of the first true leaves of the cotton, winged plant-lice or aphids appear in large numbers on the under side of these leaves and on the terminals, the "buds" of the plants often being black with them. Almost all of these are of the same species as that which infests melons later in the season, namely, *Aphis gossypii* Glov. (fig. 2). It may not be out of place, therefore, to call attention to the undesirability of planting cotton between rows of melons, as is often done. The plant-lice migrate to the cotton at this time from various common weeds upon which they have passed the winter.

Another plant-louse, *Aphis* sp., which is most commonly found on bur clover, occurs on the cotton plant at the same time and can not easily be distinguished from the first-mentioned species. In cold weather these plant-lice often cause considerable injury to the cotton plants and greatly retard their development, since they multiply very rapidly and feed mostly on the growing terminals. If there be a few

warm days, however, hordes of small parasitic flies appear and in a few days often completely rid the plants of aphids.

Remedies.—Although these plant-lice may be readily destroyed by spraying with kerosene emulsion, whale-oil soap, or tobacco water, as the writer has demonstrated, yet it would hardly seem, judging from his observations, that the use of these insecticides will as a rule be profitable in this particular case. Fall and winter plowing which will keep the fields clear of weeds during the winter will undoubtedly have a

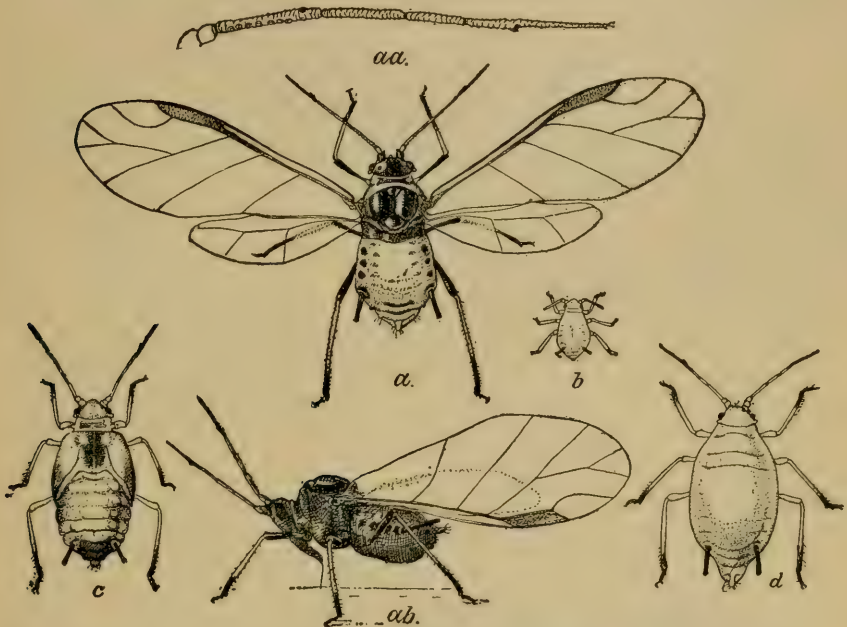


FIG. 2.—*Aphis gossypii*: *a*, winged female; *aa*, enlarged antenna of same; *ab*, dark female, side view; *b*, young nymph or larva; *c*, last stage of nymph; *d*, wingless female—all greatly enlarged (after Chittenden).

beneficial effect in reducing the numbers of plant-lice, and in some cases will be the only treatment necessary.

THE GARDEN WEBWORM.

The so-called "webworms" or "careless worms" (*Loxostege similis* Guen.) often destroy young cotton and corn over considerable areas, as was especially the case in northern Texas and in Oklahoma in 1903. The name "careless worm" is derived from the normal food plant of the species, the "careless weed" (*Amaranthus*), upon which these webworms always feed by preference. It is in fields grown up to these weeds that the caterpillars are always worst, and if these are kept down the insects will be much less troublesome.

Life history.—The winter is passed in the ground either in the larval or pupal stage and the first moths appear by the middle of April. These moths are of a yellowish-buff color, with markings as shown in figure 3, *a*. Their eggs, which, to the number of 50 per moth, are deposited in bunches of from 8 to 20 upon the leaves of the food plant, and hatch in about three days. The larvæ of the first two broods feed upon weeds, or often upon alfalfa, where that is grown, in which case they are driven to migrate to adjoining cotton when alfalfa is cut. The full-grown caterpillars are slightly over an inch long and of a yellowish or yellowish-green color, marked with shining black tubercles, or warts, as shown in figure 3, *b*. The second brood of larvæ,

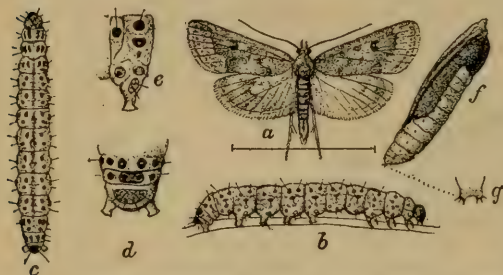


FIG. 3.—*Loxostege similis*: *a*, male moth; *b*, larva, lateral view; *c*, larva, dorsal view; *d*, anal segment; *e*, abdominal segment, lateral view; *f*, pupa; *g*, cremaster—*a*, *b*, *c*, *f*, somewhat enlarged; *d*, *e*, *g*, more enlarged (reengraved after Riley, except *c*, from Chittenden).

which occurs in late May and the first half of June, is the one most injurious to cotton. In feeding, the caterpillars spin a fine web which envelops the leaves of the young cotton plant. When full grown they enter the soil and there transform to pupæ (see fig. 3, *f*), from which the moths emerge in about eight days, or just a month from the time the eggs were laid. As a rule, no appreciable injury is inflicted on older cotton, but in August alfalfa is often damaged. There seem to be five, and possibly six, broods a year in Texas. Corn and all kinds of garden vegetables are injured at about the same time as is cotton.

Remedies.—It is evident that fall and winter plowing, not only of cultivated land but also of adjoining fields grown up to weeds, is the most effective means of controlling this pest. Upon their appearance the caterpillars may be easily destroyed by dusting with Paris green or any similar arsenical which will not burn the foliage. This may be best accomplished by means of a powder gun which will distribute a small but ample amount of the poison evenly over the plant, thus economizing in the amount of material used and avoiding the burning of the tender foliage which might result from the heavier application by means of a bag. The planter will find that the prompt application of Paris green will be entirely effectual.

THE WHITE-LINED SPHINX CATERPILLAR.

The larvæ of the white-lined sphinx moth (*Deilephila lineata* Fab.) are common inhabitants of fields of young cotton, but usually do not work any appreciable amount of injury. They are subject to consid-

erable variation in color, being either yellowish-green with black eye spots and faint stripes, or black with yellowish spots, as shown in figure 4. They may be readily distinguished from all other caterpillars on cotton by the pointed horn at the end of the body. Occasionally they become excessively numerous and, assembling in great numbers, somewhat like the army worm, destroy all low-growing vegetation in their path. Such was the case in 1903, when late in May serious damage

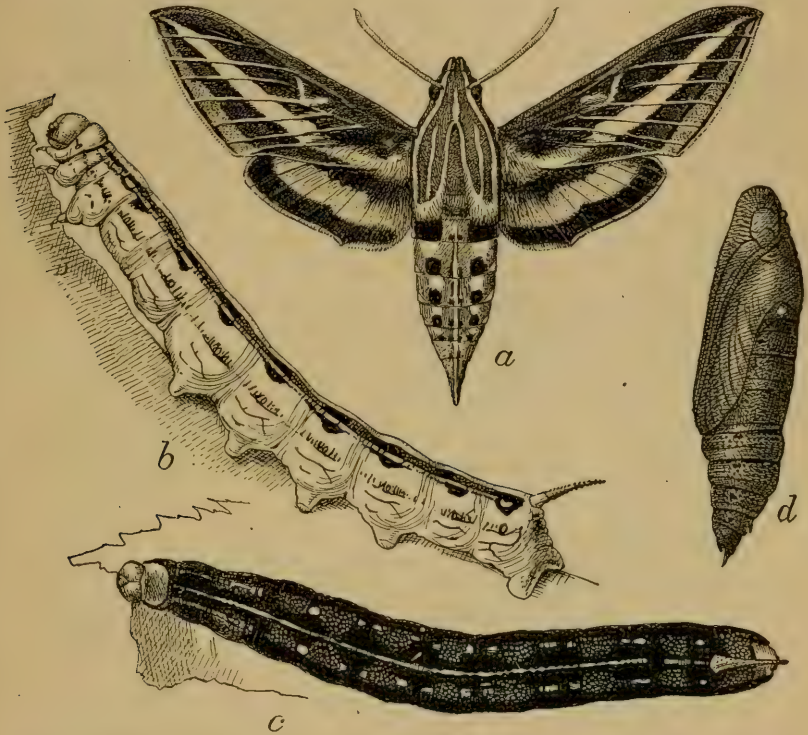


FIG. 4.—*Deilephila lineata*: a, moth; b, pale larva; c, dark form of larva; d, pupa—all natural size (from Chittenden).

was inflicted on cotton and garden crops in several localities in southwestern Texas.

Life history.—When full grown the caterpillars enter the earth to pupate and the moths emerge about July 1. Usually most of the moths fail to emerge, however, as the caterpillars are parasitized by one of the tachina flies to such an extent that but few transform. The second brood is therefore very small and does no harm. The winter is passed in the soil in the pupal stage.

Remedies.—The favorite food of these caterpillars is purslane, though many succulent weeds are among its common food plants. Here again, therefore, the destruction of these weeds and thorough winter plow-

ing are the best means of control. The caterpillars are readily seen and may easily be destroyed by hand while chopping the cotton; and this should be done, as one caterpillar can destroy several plants if left unmolested. When present in large numbers they may be readily destroyed by dusting the vegetation upon which they are feeding with Paris green.

GRASSHOPPERS.

The differential locust (*Melanoplus differentialis* Thos.) is by far the most injurious grasshopper in Texas. In the summer of 1903 the adults severely injured cotton and corn in the south-central part of the State; and in the spring of 1904 the young, just after they had hatched from the eggs, destroyed the young cotton and corn plants to an alarming extent throughout several counties in this section, but particularly in the bottom lands along the Brazos River and its tributaries. The eggs commenced to hatch in numbers by the middle of March, 1904, and by April 1 the young were present in many fields in countless numbers, destroying the young plants and necessitating replanting over large fields. The eggs had been laid along the edges of cultivated fields, along ditches, and in fields which had been uncultivated the previous year. (See figs. 5 to 8.)

Remedies.—It was found that by thoroughly dusting the weeds around the fields with Paris green, either pure or diluted with flour.



FIG. 5.—*Melanoplus differentialis*: adult—enlarged (original).

great numbers of the nymphs were killed. In addition, a large spoonful of poisoned bran mash was placed every 3 feet in the row throughout the fields and the plants were dusted. This treatment proved very effective, 20 or 30 dead grasshoppers being found near a pile of the mash. This mash is made by stirring 1 pound of white arsenic or Paris green into 25 pounds of bran or middlings and then adding 1 quart of cheap molasses diluted with sufficient water to thoroughly moisten the whole mass, but not so much as to make it doughy. If too moist it cakes too quickly in the sun. It was found that the mash was nearly as effective without the molasses. Where the young hoppers occurred in immense numbers—for they often formed a small cloud when first disturbed—they were sprayed with pure kerosene or crude petroleum, or a soap emulsion containing

about 15 per cent kerosene or crude petroleum. Results with the pure oils were more quickly apparent, so that these were preferred by the planters. Thousands of grasshoppers were thus destroyed within a few square feet. By a thorough use of these methods, as local circumstances warranted, the planters were able to so reduce the numbers of grasshoppers that they did but little damage after the latter part of April. About this time, also, large flocks of ricebirds and blackbirds appeared and fed on the grasshoppers for several days. Had the outbreak remained unchecked several replantings would have been necessary, and a recurrence of the pest the next season would have been probable.

This outbreak, as well as the previous ones, was undoubtedly due to the large areas of uncultivated land in the river bottoms in 1903, as a result of the floods of the summer of 1902 and the spring of 1903. These uncultivated fields, grown up to rank weeds which are the favorite food of the grasshoppers and with a hard, baked soil, furnished an ideal place for them to multiply and in which to lay their eggs in the fall of 1903. From

these fields and from uncultivated fence rows the young emerged in the spring of 1904, and in many cases it was difficult to successfully cope with them, owing to the fact that the fields from which they emerged remained uncultivated and in them nothing was done toward checking the pest.



FIG. 6.—*Melanoplus differentialis* on corn leaves: nymph in natural position, upper figure; pupa skin below on right—(original).

The grasshoppers become full grown late in June, and the eggs are laid in the ground during August and September, usually in a firm, hard soil such as that described above. It is evident, therefore, that where large areas of land are left uncultivated and wide strips of



FIG. 7.—*Melanoplus differentialis*: young nymph—enlarged (original).

uncultivated ground grown up in weeds surround the fields, an ideal place is furnished for the grasshoppers to multiply and oviposit; and being too numerous to subsist upon the vegetation there found, the young hatching from these eggs migrate to fields of cultivated crops.



FIG. 8.—Egg mass of *Melanoplus differentialis*—enlarged (original).

It has been repeatedly demonstrated that the very best method of controlling such outbreaks is to thoroughly plow and harrow all land where the eggs are laid in the fall as soon as possible after they are deposited. If this be done serious injury will be rare, but if neglected the planter should

be prepared to combat the young as soon as they hatch with the remedial measures above outlined, for they are by no means so easily or effectively poisoned when full grown or nearly so.

The large lubber grasshopper.—In southwestern and west-central Texas the large lubber grasshopper (*Brachystola magna* Gir.) (fig. 9)

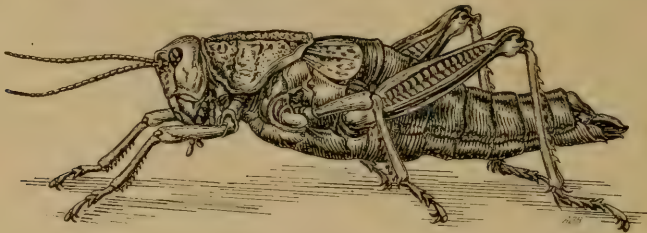


FIG. 9.—*Brachystola magna* (original).

often occurs in large numbers and destroys fields of cotton, as it takes but a short time for one of these huge insects to ruin a plant. The chief damage is done late in May and in June and mostly to cotton, this crop seeming to be a favorite with them, though they are found in

pastures far away from farms. The habits of this species are not well known, but it seems probable that the grasshoppers deposit their eggs in grass land, as it is said that they are not injurious where hogs are allowed free range. They may be controlled by a liberal use of the poisoned bran mash above described, but it should be applied as soon as they appear.

WINGLESS MAY BEETLES.

Two species of wingless May beetles (*Lachnosterna lanceolata* Say and *L. cribrata* Lec.) often seriously injure young cotton, as well as various other crops, especially garden truck, in the arable land west of the ninety-seventh meridian. Frequently they occur in immense numbers and cut off the young cotton plants over a large field. As they are wingless they may be readily caught by hand picking or they may be poisoned by dusting the plants and all weeds with Paris green.

The first of these species (fig. 10) is of a grayish tinge, and is more injurious in west-central counties than elsewhere, although it also occurs in northern Texas. It feeds upon careless weed (*Amaranthus*) and wild sunflower (*Helianthus*). *L. cribrata* (fig. 11) has been reported from all parts of northwestern Texas as injurious to cotton and all sorts of garden stuff. It prefers the ragweed to all other food plants. A third species (*L. foveata* Lec.) is more common in the southwestern part of the State, where it has often been injurious. It has similar habits to the wingless species, but is usually provided with wings.

The species have much in common, although the complete life histories and habits are not known. The last two species emerge from the soil—where they remain hidden during the day—about an hour before sundown and feed from then until dusk, when they return to the holes left or make new ones. Their globular, colorless eggs are laid in June about two inches deep in the



FIG. 10.—*Lachnosterna lanceolata*: female—somewhat enlarged (original).

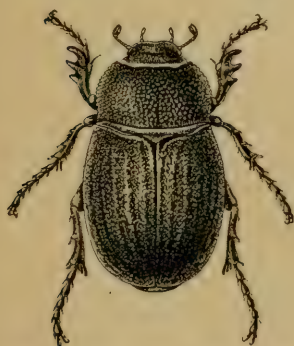


FIG. 11.—*Lachnosterna cribrata*: female—enlarged (original).

soil, and the larvæ feed on the roots of various weeds and grasses, but have never been observed as injurious. It has been noted that the beetles are the most injurious where a field has been allowed to grow up to weeds the previous summer, and that where the land has

been plowed in the winter and cultivated in early spring they are by no means as abundant as usual.

INSECTS WHICH INJURE THE LEAVES.

The salt-marsh caterpillar (*Estigmene acrea* Dru.).—This is one of the so-called "woolly bear" caterpillars, being about two inches long, black, and covered with long black and red hairs. (See fig. 12.) The caterpillars have been reported as stripping cotton of its foliage in May at Paris, Tex., in 1885, and in July in southern Texas in 1903. The loose cocoon in which the larva transforms to the pupa is made among

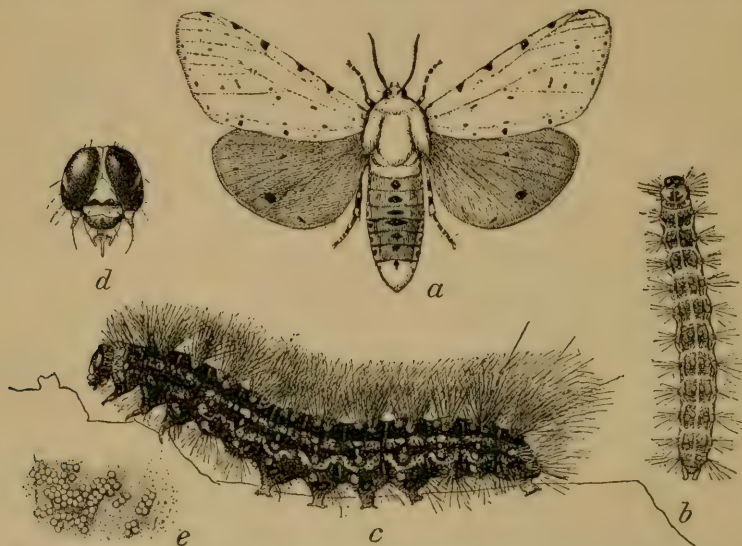


FIG. 12.—*Estigmene acrea*: a, female moth; b, half-grown larva; c, mature larva, lateral view; d, head of same, front view; e, egg mass—all slightly enlarged except d, more enlarged (from Chittenden.)

the leaves of the cotton or more often in rubbish on the ground. From these the moths emerge in about two weeks, the complete life cycle occupying about forty-five days. There are probably four broods in a year. These caterpillars have been reported to be unsusceptible to poisoning with Paris green when full grown, but like many others could probably be killed without difficulty if poisoned while still young.

The arge tiger moth (*Apantesis arge* Dru.).—A similar caterpillar is common upon cotton, but has never been as injurious as is the salt-marsh caterpillar.

The beet army worm (*Caradrina virigua* Hbn.).—A small green caterpillar, about an inch long, which in Colorado and California has been a serious enemy to sugar beets and is known as the beet army worm,

is worthy of note on account of its past records elsewhere. It has been found commonly in northern Texas feeding on cotton foliage and eating into the squares. The different stages are shown in figure 13. It is readily controlled by means of arsenicals.

The fall army worm (*Laphygma frugiperda* S. & A.).—Occasionally the larvæ of the fall army worm stray into the cotton fields when they become excessively abundant—in late summer or early fall—and sometimes do local injury to the foliage.

The Io moth (*Automeris io* Fab.).—The green, spine-covered larvæ of this moth are not uncommon on cotton and will be easily recognized if handled, as the prick of the spines is poisonous.

The cotton-boll cutworm (*Prodenia ornithogalli* Guen.) (figs. 14 and 15).—Throughout the season the caterpillars of this so-called cutworm

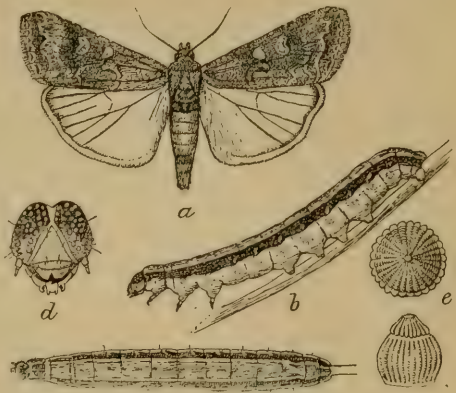


FIG. 13.—*Caradrina exigua*: a, moth; b, larva, lateral view; c, larva, dorsal view; d, head of larva; e, egg, viewed from above; f, egg, from side—all enlarged (e, f, after Hofmann; a-d, after Chittenden).



FIG. 14.—*Prodenia ornithogalli*: dark form, male, above; pale form, female, below—somewhat enlarged (from Chittenden).

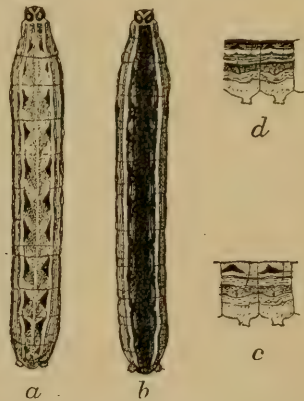


FIG. 15.—*Prodenia ornithogalli*: a, pale form of larva; b, dark form of same; c, lateral view of abdominal proleg segments of pale form; d, same of dark form—all enlarged (from Chittenden).

are found eating the foliage and boring into the squares and bolls much as does the bollworm. But in habits they are quite different from the true cutworms, feeding by day and not cutting off the stems of the young plants. The olive or greenish-brown caterpillars may

be readily recognized by the two rows of triangular, velvety-black spots extending down the back, as shown in figure 15. Four or five broods occur in a year in Texas. These caterpillars have never been reported as seriously injurious to cotton, but they often do considerable local damage to the squares and bolls. By picking them off of the young cotton when chopping in the spring, they may be largely controlled.

Leaf-cutting ant (*Ecodoma fervens* Say.).—Especially in southern Texas, cotton, as well as fruit trees and garden crops, often suffers from the devastations of the leaf-cutting ants, which cut off pieces of the leaves and carry them to their nests. Here they form the founda-

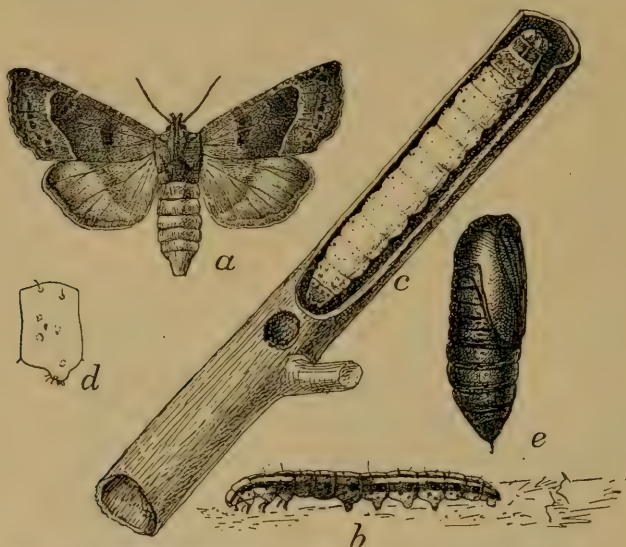


FIG. 16.—*Papaipema nitela*: a, female moth; b, half-grown larva; c, mature larva in injured stalk; d, lateral view of abdominal segment of same; e, pupa—all somewhat enlarged (from Chittenden).

tion upon which grows a fungus which is the food of the larvæ. These ants are one of the worst insect pests in the Tropics. Recently Prof. M. T. Cook, entomologist of the Cuban department of agriculture, has found that by sprinkling Paris green freely around the entrances of the nests the ants will carry it into the nests and the larvæ will be killed by it at slight expense. This promises to be the best means of controlling the ants where there are many nests, as in Cuba. The remedy which has been most used for this and ants with similar habits consists in injecting carbon bisulphid (locally known in Texas as "high life") and then closing the holes with earth. The heavy fumes will descend into the nest and destroy the occupants. The amount necessary will depend upon the size of the nest, as an individual nest is often quite large.

INSECTS WHICH INJURE THE STALK.

A number of insects are frequently found boring into or otherwise injuring the stalks, but we know of no case in which the injury has been serious.

The stalk borer (*Papaipema nitela* Guen.) (fig. 16).—This insect, which is quite different from other common borers, being black, with white stripes in its early stages, has been noticed boring into the stems several inches above the ground and causing the plants to wilt. It commonly feeds in various weeds, most commonly in the so-called "bloodweed."

The small jet-black beetles of *Amphicerus fortis* Lec., nearly related to the apple twig-borer, are often found in considerable numbers in the old cotton stalks in the spring, but have never been noted as injuring the growing plants.

The cotton-stalk borer.—One of the long-horn beetles, *Ataxia crypta* Say, whose larvæ commonly bore in the stalks of the cocklebur, sometimes bores into cotton stalks otherwise injured, but is not known to injure healthy plants.

The snowy tree cricket (*Ecanthus niveus* DeG.).—Mention should be made of the eggs of this insect, which are deposited in the stalks of cotton and various common weeds in the fall, since they have been frequently thought to be eggs of the boll weevil. These eggs are laid in a long row, leaving a long scar, composed of numerous punctures on the surface. They are deposited in the fall after the cotton is about grown and do no harm, so far as we are aware. The young which hatch from them the following spring, as well as the adults, feed very largely upon plant-lice, and are therefore more beneficial than injurious.

INSECTS WHICH INJURE THE SQUARES AND BOLLS.

The cotton square-borer (*Uranotes melinus* Hbn.).—During late May and in June cotton squares are often bored into by a small green caterpillar which many planters consider a stage of the bollworm and others have called the "sharpshooter." Injury from this cause is often quite serious for a short time on a small area, as we have seen 10 per cent of the stalks entirely denuded of squares in small fields where this insect is abundant. The caterpillars hollow out the squares in the same manner as does the bollworm, often destroying all of those on a plant knee high and even boring into the stalk. They are bright green, oval, decidedly flattened, covered with short hairs which give them a velvety appearance, and with the head retracted under the front of the body, being quite unlike any stage of the bollworm. They are the larvæ of a dainty little butterfly (shown slightly enlarged

in fig. 17) which is very common around cotton fields. The eggs are laid on the leaves and stems of cotton, cowpeas, goatweed and various weeds. The larvæ have also been commonly found on hops, beans, and cowpeas, and seem to prefer the latter to cotton.

Fortunately for the planter, the large majority of the caterpillars

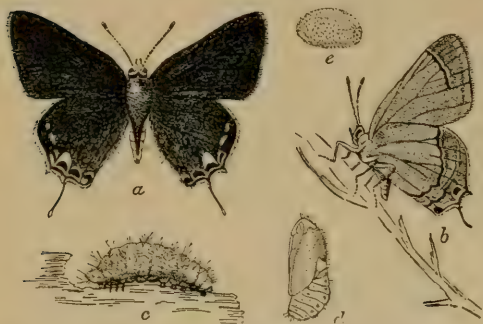


FIG. 17.—*Uranotes melinus*: a, dorsal view of butterfly; b, butterfly, with wings closed; c, larva from side; d, pupa; e, egg—all somewhat enlarged, except e, greatly enlarged (all except e redrawn from Howard).

are usually parasitized by flies about the size of the housefly and also by small, wasp-like hymenopterous insects. The parasitic flies lay their eggs upon the caterpillar, and the maggots hatching from them bore into the caterpillar and feed upon its tissues, ultimately killing it and emerging from it or the pupa as adult flies.

Over 90 per cent of the June brood have been found thus

killed. It is usually hardly worth while, therefore, to attempt to combat this insect, as it is not often seriously injurious in the same locality year after year. Should remedial treatment be necessary, thorough dusting with Paris green would probably answer the purpose, as the young caterpillars, as do bollworms, feed to some extent upon the foliage before entering the squares.

Cotton "sharpshooters."—

Every summer late in July and August frequent reports are made of considerable injury to cotton by "sharpshooters," especially on low land. These insects are reported to puncture the squares and bolls, causing them to drop prematurely, a small black speck showing the point where punctured.



FIG. 18.—*Homalodisca triquetra*: adult at left, last stage of nymph at right, young nymph below—all enlarged (original).

Very few planters, however, are able to identify the insect blamed for the trouble. The insect which has commonly been credited with this work is the glassy-winged sharpshooter (*Homalodisca triquetra*

Fab.) (fig. 18), but with it are associated several near relatives with similar habits—*Oncometopia undata* Fab. (fig. 19), *O. lateralis* Fab. (fig. 20), and *Aulucizes irrorata* Fab. (fig. 21). Many planters know these insects as “dodgers,” from their habit of quickly dodging to the opposite side of the stem when disturbed, and those familiar with them have thought them harmless.

Extended observation during two seasons has failed to show any injury to cotton done by these insects. Repeated experiments with the insects in confinement have failed to show that they ever puncture the squares and bolls. There seems to be not the slightest evidence that the insects are ever injurious to cotton, and the supposed injury is undoubtedly due to a physiological condition of the plant which, at the season when the supposed injury occurs, causes a marked shedding of the fruit.

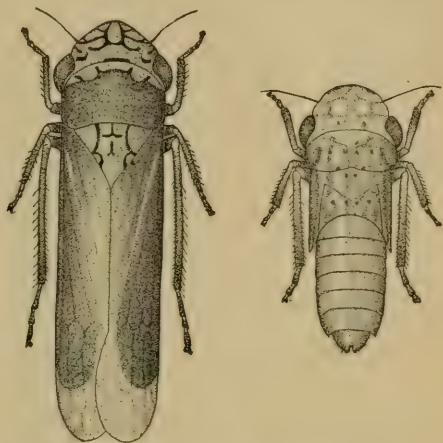


FIG. 19.—*Oncometopia undata*: adult at left, nymph at right—greatly enlarged (original).

The adult insects hibernate in rubbish on the ground near the food plants and appear in early spring on the elm, yaupon, hackberry, redbud, cottonwood, willow, and the tender shoots of other trees, especially on bottom land along the streams, where these



FIG. 20.—*Oncometopia lateralis*: adult and nymph—greatly enlarged (original).

trees are most common. Here they suck the juices of the tender leaves and terminals and deposit their eggs in the tender leaves and stems. The eggs are laid in a row of 10 to 15, side by side, just under the surface of the leaf, forming a blister-like mark. They hatch in a few days and the young bugs feed in the same places as do their parents. The young bugs, or nymphs, shown in figures 18, 19, 20, are grayish or yellowish in color and resemble the adults,



FIG. 21.—*Aulucizes irrorata*: adult—much enlarged (original).

except that they lack wings. Two or three annual generations occur in Texas. The insects are not usually common on cotton until mid-summer, and even then are by no means as abundant as on the trees mentioned. They are exceedingly fond of banana trees, sorghum, and sunflowers, sometimes injuring the latter considerably. Records of any injury to cultivated crops by the glassy-winged sharpshooter, the most common species on cotton, are exceedingly rare and doubtful, and there is no evidence whatever for considering it an enemy to cotton.

The cotton leaf-bug (*Calocoris rapidus* Say).—This insect was the

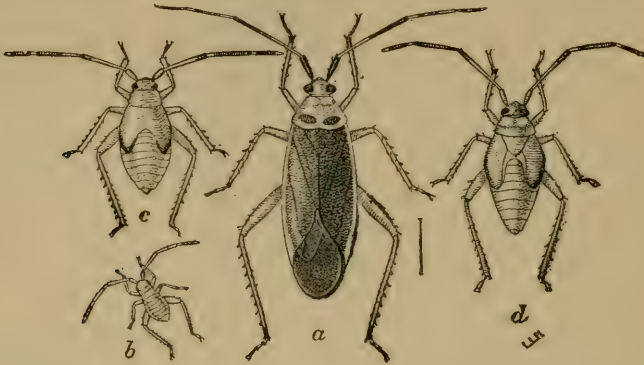


FIG. 22.—Cotton leaf-bug, *Calocoris rapidus*: a, mature bug; b, young nymph; c, fourth stage of nymph; d, fifth stage of young (original).

cause of considerable damage in northern Texas in August and September, 1904. It punctured the squares and young bolls, either causing them to drop, or making the bolls shrivel or decay where punctured. The punctures in the bolls are indicated by small round black spots resembling diseased places, which gradually become larger and sunken (fig. 23). This insect has been known as a common inhabitant of cotton fields for many years, but injury seems to have been rare. It may be readily recognized by the bright red spots just beyond the middle of the wing. The young are shown in figure 22, and are light green marked with red. Several annual generations of the insect occur, but its habits outside of the cotton field are unknown. No successful means of combating it has yet been devised.



FIG. 23.—Cotton boll showing punctures of *Calocoris rapidus* (original).

Other plant-bugs.—Similar injury to bolls, causing black spots and shrinking or decay, is caused by the large green plant bugs variously known as “pumpkin bugs,” “stink bugs”—from the very disagreeable odor emitted—and by other local names.

The most common of these is *Nezara hilaris* Say, shown in figure 24. It is bright green in color, and is undoubtedly a decidedly injurious insect, as it has been known to attack orange trees in Florida and strawberries and other garden crops elsewhere.

The leaf-footed plant-bugs (*Leptoglossus phyllopus* Linn. and *L. oppositus* Say) (figs. 25 and 26) injure the bolls in the same manner. These insects are also serious enemies of peaches and tomatoes in Texas. They

breed commonly on thistles and should be destroyed wherever found.

Two other bugs somewhat resembling the so-called "cotton stainer," though of a slaty or bluish color, margined with yellow or red, *Largus*

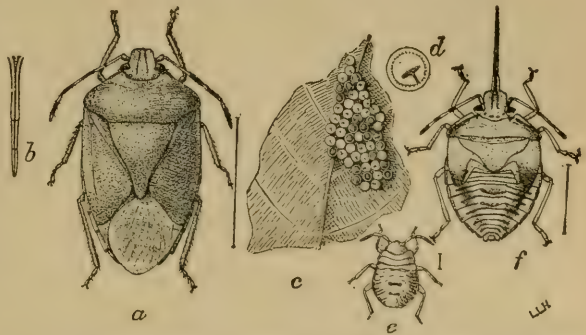


FIG. 24.—*Nezara hilaris*: a, mature bug; b, beak of same; c, egg mass; d, single egg; e, young nymph; f, last stage of nymph—all enlarged; b, d, more enlarged (from Chittenden, unpublished).



FIG. 25.—*Leptoglossus phyllopus*, twice natural size (after Hubbard).



FIG. 26.—*Leptoglossus oppositus*—twice natural size (from Chittenden.)

succinctus Linn. and *Jadera hæmatoloma* H.-Schf., are frequently found in considerable numbers on the bolls and do some damage. The young nymphs feed upon low-growing weeds and have not been observed on cotton. There is no evidence of any injury in Texas by the so-called "cotton stainer" (*Dysdercus suturellus* H.-Schf.).

Click-beetle.—A small species of click-beetle (*Monocrepidius vesperinus* Fab.), shown in figure 27, is frequently found on cotton blossoms

and squares and working around holes made by the bollworm or square borer. It is of interest because frequently mistaken for the boll weevil where that insect is not well known. There is some evidence that these beetles sometimes eat into a square, but if so, the injury is rare and inconsequential.



FIG. 27.—*Monocrepidius vespertinus*—enlarged (from Chittenden).

The cowpea-pod weevil (*Chalcodermus æneus* Boh.) (fig. 28).—This is commonly an enemy of cowpea, working in the pods and seeds of the developing peas, but has been observed eating into the stems of young cotton plants and sometimes attacking the young squares in Texas, Louisiana, and Georgia, the injury being more severe in the latter State, where cowpeas are more commonly raised. It is frequently mistaken for the boll weevil.

Bruchus amicus Horn.—This small gray beetle, which quite closely resembles the pea weevil, has been observed upon cotton squares in southwestern Texas and was thought to be injurious, but was probably merely feeding upon nectar, as it breeds in the pods of the mesquite.

Acorn weevils.—Various species of acorn weevils (*Balaninus* spp.) are frequently found on cotton, especially near woods, and may occasionally be seen feeding on squares. They never do material injury, but may easily be mistaken for the boll



FIG. 28.—*Chalcodermus æneus*—enlarged (from Chittenden).

weevil by those unacquainted with the latter pest.

Blister beetles.—Blister beetles of various species (*Epicauta vittata* Fab., *E. lemniscata* Fab. (fig. 29), *E. cinerea* Forst., and *E. ferruginea* Say) are frequently found eating holes in the cotton flowers, but never in sufficient numbers to cause material injury.

A large number of common insects are found upon the cotton plant, some frequenting it habitually and others merely accidentally, but the above are the only ones observed as injurious in Texas in recent years.

CONCLUSION.

FIG. 29.—*Epicauta lemniscata*—enlarged (from Chittenden).

It will have been observed that most of the common insect enemies of cotton above described naturally feed upon various common weeds which grow up in neglected or uncultivated fields, and that, by the destruction of such weeds, and winter plowing where they have grown, the insects

inhabiting them will be largely controlled. The thorough cultivation, during the late fall, winter, and early spring, of all land to be planted, or which has been infested, will also be the means of greatly reducing their numbers by killing many of the stages then hibernating in the soil. These two general principles must be relied upon to a large extent for the control of most of the minor cotton insects. When they become overabundant those leaf-eaters which chew their food may be poisoned with Paris green or other arsenicals, used as a dust or made into a mash with bran.

More intensive cultivation will undoubtedly result in a material lessening of injury by these pests, for in the eastern cotton-growing States they are by no means as injurious as in Texas, so far as the records indicate. The better methods of cotton culture generally recommended by this Department during the past few years will undoubtedly result in the lessening of injury by all the more common cotton insects.



Farmers' Bulletin No. 247

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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 247.

THE
CONTROL OF THE CODLING MOTH
AND APPLE SCAB.

BY

C. L. MARLATT,

OF THE BUREAU OF ENTOMOLOGY,

AND

W. A. ORTON,

OF THE BUREAU OF PLANT INDUSTRY.

[Revised edition, August, 1906.]



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1906.

LETTER OF TRANSMITTAL

UNITED STATES DEPARTMENT OF AGRICULTURE,
Washington, D. C., July 11, 1906.

SIR: We have the honor to transmit herewith a paper entitled "The Control of the Codling Moth and Apple Scab," by C. L. Marlatt, of the Bureau of Entomology, and W. A. Orton, of the Bureau of Plant Industry.

This bulletin deals only with the two principal enemies of the apple, namely, the chief insect enemy, the codling moth, and the principal fungous disease, apple scab. The reason for such joint publication arises from the fact that the remedial treatment for both of these is of such a nature that the applications can be combined at a lessening of nearly one-half the cost of time and labor. The bulletin includes a brief but plain statement of the nature of the codling moth and the means of controlling it, followed by a similar portion relating to apple scab, and concluding with the combined directions for spraying, and a spray calendar. We recommend the republication of this paper as Farmers' Bulletin No. 247, revised, the original edition having appeared March 7, 1906.

Respectfully,

L. O. HOWARD,
Chief, Bureau of Entomology.

B. T. GALLOWAY,
Chief, Bureau of Plant Industry.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE CONTROL OF THE CODLING MOTH AND APPLE SCAB.

INTRODUCTION.

The codling moth or apple worm and the apple scab have no direct relationship, except that both attack the apple and are, respectively, the chief insect enemy and, in the Northern States, the chief fungous disease of this fruit. Both are, however, subject to practical control by sprays, which, being necessary at the same dates, in the main, can be combined in single applications, and it is for this reason that they are considered together in this bulletin. A brief life history is given of the codling moth, with a description of the sprays and other remedies for it, followed by similar matter on the apple scab. The bulletin concludes with a joint consideration, for both pests, of spraying outfits and methods, with directions for the combination of the spray mixtures, and a spray calendar.

THE CODLING MOTH.

(*Carpocapsa pomonella* L.)

LOSSES DUE TO THE CODLING MOTH.

The codling moth or apple worm is a familiar pest to every grower or consumer of apples, and a wormy apple, the result of its work, scarcely needs description. The larva, living most of its life within the fruit, throws out through its entrance hole, which it enlarges from time to time, or through its exit hole in the side of the fruit, the characteristic mass of frass or excrement which is the sign of infestation. Such an apple is practically unsalable or, at best, fetches a very small price, either for consumption or for working up into cider. The monetary loss thus occasioned by this insect is greater than that due to any other insect pest affecting fruits.

It has been shown by careful estimates in various apple-growing States that this insect may cause a loss of from 20 to 40 per cent of the fruit which would otherwise be sound and merchantable. Without going into details, this loss, on the lowest or 20 per cent basis, amounts annually to \$11,400,000 in the United States, and this does not include the expenditures for spraying trees with arsenicals, which

amount to more than \$8,000,000 additional, indicating a total loss chargeable to the codling moth of nearly \$20,000,000. Great as this loss still is, it has been very much limited by measures of control which are becoming more and more widely adopted, and many apple growers in badly infested regions are now saving every year more than 85 per cent of fruit which would, without treatment, be wormy.

The following account of the codling moth, with directions for control, is abbreviated and recast from Farmers' Bulletin No. 171, by Mr. C. B. Simpson, formerly a special agent of the then Division of Entomology, who made a three years' investigation of the codling moth in the Northwest.

DISTRIBUTION.

The original home of this insect was probably southeastern Europe, the home of the apple, but it has followed closely upon the distribution of the apple until it is now found in almost every country in the world. It is spread principally by the shipping of the infested fruit. The young larvæ in such fruit complete their development, and leaving the fruit spin cocoons on the crates or near by, the moths emerging in due course and flying to the nearest orchard to deposit their eggs. When orchards are but a little distance apart the moths may fly from one orchard into another.

FRUITS INFESTED.

The apple is the natural food of this insect, and sustains almost all the loss occasioned by it. Pears are next in order of infestation, but if apples are present in the same orchard pears are usually not badly infested. The codling moth larvæ have been found also in the fruit of quince, prune, plum, peach, and cherry, but never in sufficient numbers to cause any great injury.

LIFE HISTORY.

Every fruit grower should familiarize himself with the different stages of this insect by studying it in his own orchard, so that he will understand the principles of control, which are based on certain vulnerable points in its life cycle.

Hibernation.—The codling moth passes the winter in the larval stage in silken cocoons in cracks and holes in the trees and in houses where apples have been stored. In the spring these larvæ change to pupæ, and the moths emerge about a month after the apple is in blossom.

The moth.—The moth (fig. 1, *a*) is but little known among fruit growers, and other moths are often mistaken for it. It varies somewhat in size, but the maximum spread of its wings is about three-fourths of an inch. The front wings are of a brownish gray color

and are crossed with lines of gray scales, giving them the appearance of watered silk. At the tips of the wings there is a large brown spot, in which are many scales of bronze or gold. The hind wings are grayish brown in color. Taken as a whole, the coloring of the moth is such that when resting on old grayish bark it is so like the bark that it is not easily distinguished. The moth lays her eggs, a few days after emergence, on the leaves of apple or other food plant, or on the fruit. A majority of the eggs of the first generation are laid on the leaves, while the greater part of those of the second generation are laid upon the fruit.

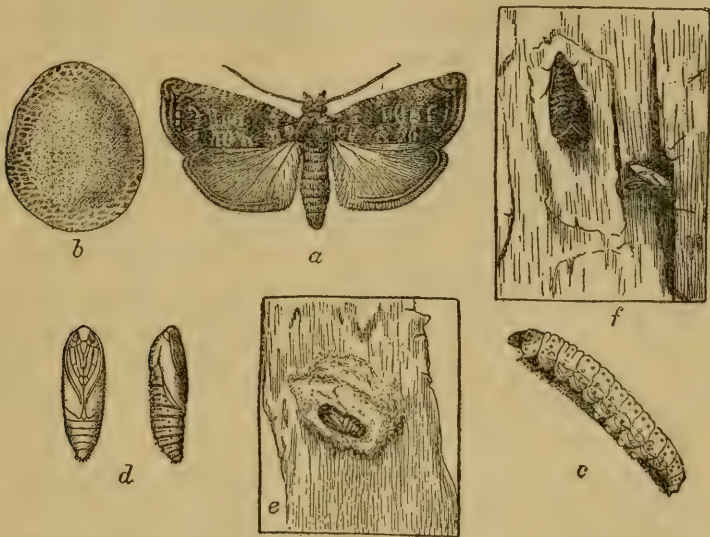


FIG. 1.—The codling moth: *a*, the moth or adult insect, slightly enlarged; *b*, the egg, greatly enlarged; *c*, the full-grown larva, slightly enlarged; *d*, the pupa, slightly enlarged; *e*, the pupa in its cocoon on the inner surface of a piece of bark, reduced about one-half; *f*, moth on bark and empty pupa skin from which it emerged, about natural size (from Simpson).

The egg.—The eggs are very minute, scarcely visible to the naked eye, and pearly white in color, resembling thin convex disks. Around the edge there is a coarse network of ridges; while toward the center these ridges are finer, as illustrated in fig. 1 at *b*. A red ring, which indicates the embryo or developing larva, appears in the egg a few days after it is laid. In about eleven days, varying somewhat with temperature, the young larva breaks its way out of the shell and seeks to enter the fruit.

The larva.—This is the most important stage of the insect, for not only does it work its injury in the larval condition, but that is the stage in which it is most amenable to remedial measures.

A large number of the larvæ which hatch from eggs deposited on the leaves eat small portions of the leaves before finding fruit. The

larvæ have some difficulty in entering the smooth sides of the fruit, and about 80 per cent of the first generation enter by way of the calyx, while the majority of the second generation enter at the sides, especially where the fruits are touching.

Before entering the young apple the larva feeds, as noted, on the leaves, but also for a day or two within the partial concealment formed by the calyx or blossom end of the apple. During several days, therefore, the little apple worms feed externally, both before they enter the calyx and within the latter, and the object of spraying is to insure their being poisoned by thoroughly coating in advance, with an arsenical mixture, the leaves, and especially the blossom end of every fruit, before the shutting up of the lobes of the calyx. Most of the larvæ enter the calyx after it is closed, and are then beyond the reach of any poison later applied.

The pinkish larva lives in the fruit about twenty days, and grows to a length of about five-eighths of an inch (fig. 1, *c*), when, being full fed, it makes a tunnel to the outside of the fruit, the entrance of which is filled with frass and silk. When ready to leave the apple this plug is pushed out. The larva then crawls out and immediately seeks a place in which to spin its cocoon.

The cocoon.—Cocoons have been observed in the following places: In holes and cracks in the trunks and branches of the trees; under rough bark (fig. 1, *c*); in the fruits (though rarely); in the cracks in the ground around the tree: on or between the clods among the fallen fruit; under hands or anything else resting on or against the tree; in cracks and angles of the walls and roof of the building in which apples are stored; under shingles of buildings near apple trees; in fence posts and under pickets of near-by fences; in paper or other rubbish on the ground; and in various other places. The cocoons of the first generation are composed entirely of silk, while in those of the second generation are incorporated bits of wood and bark. The larvæ inside the cocoons transform into pupæ in about six days from the time of spinning the cocoon.

The pupa.—The pupa (fig. 1, *d*) is yellowish at first, but changes to a brown, and later to a bronze color. In about twenty days from the spinning of the cocoon the pupa, aided by its spines, pushes its way out of the cocoon. The pupa skin splits and the moth emerges (fig. 1, *f*), lays its eggs, and gives rise to another generation. The average life cycle of the insect is about fifty days.

GENERATIONS OF THE INSECT.

In the principal northern apple-growing sections of the United States, as, for example, New York and Maine, the insect has but one full generation, with only a partial second. In the warmer portions of the East and West two generations are found, and in the Southwest

and South a partial third generation has been distinguished. Where two full generations occur, the members of the second are much more numerous and destructive than those of the first. The dates of the different generations will vary in a given locality with the season. Taking Nebraska as representing the upper Mississippi Valley region, the first brood of the codling moth will pass from the egg to the moth stage between June 1 and August 15, the majority of the moths emerging between July 20 and August 15. The second generation overlaps the first, beginning in the egg stage about the end of July and running on to the end of the season, the larvæ of this generation hibernating. In the Southwest some of these larvæ may transform to moths and give rise to a partial third generation.

NATURAL ENEMIES.

There are many natural enemies of the codling moth which may be encouraged with advantage. It has often been noted that no larvæ can be found under the rough bark of the trees in the spring, while many are found in cracks and holes in the trunks, branches, and stubs. Under the rough bark many cocoons can be found from which the larvæ are missing, and in these cases the telltale hole made by a woodpecker can always be found. Destroying or rendering unsuitable the more secure places for spinning, thus forcing the larvæ to spin cocoons where the birds can get them, will result in destroying many of the insects.

MEASURES USED AGAINST THE CODLING MOTH.

The first essential in combating this insect is for the apple grower to familiarize himself with its life history. By doing this he is better prepared to understand the remedial measures recommended, and can modify them to suit his local conditions.

Remedies of Little or No Value.

It is sometimes as well to know what not to use against an insect as it is to know what to use. The following remedies have been suggested at various times and found to be of little or no value: Moth balls hung in the trees and supposed to keep moths away; smudging or spraying orchards with ill-smelling compounds; plugging the trees with sulphur; plugging the roots with calomel; banding trees with tarred paper to keep the larvæ from crawling up the tree; trap lanterns; baiting the moths with a mixture of vinegar and molasses; spraying with water; and electric lights as a repellent of the moth. These so-called remedies have been tried so often that a fruit grower is simply wasting his time and money when he uses them.

Banding.

The use of bands to trap the full-grown larvæ of the codling moth was the only remedial measure of value employed before arsenical sprays were discovered. If an orchard has been given good care, and spraying is thoroughly done, it may be unnecessary to use bands. If, however, the trees are old and cracked, and have holes in the trunks and branches, or are planted close together, so that spraying is difficult,

the use of bands will materially aid in bringing the insect under control.

Banding for this insect is simply affording it a good place to spin its cocoon, and killing the larva or pupa after it has gone beneath the band. Cloth bands, from 10 to 12 inches in width, are folded once lengthwise and placed around the tree. They can be fastened in such a way as to be easily removed and replaced, by driving a nail through the ends and then nipping off the head at an angle so as to leave a sharp point.



FIG. 2.—Large apple tree properly banded for the codling moth (from Simpson).

If a tree is large, one band should be placed on the trunk and one on each of the larger limbs (fig. 2). Cloth bands of any heavy, dark-colored stuff are much preferable to bands of hay or paper. When bands are used, the trees should be scraped clean of rough or loose bark, to leave as few other attractive places as possible in which the larvæ might spin cocoons. Inspection of the bands should be made regularly at intervals of ten days, and all larvæ and pupæ found beneath them should be destroyed with a knife. If used alone, banding is but little effective in badly infested localities, but it is a most valuable adjunct to spraying. Under no circumstances should banding be used as a substitute for spraying.

Spraying with Arsenical Insecticides.

Spraying with some arsenical is now recognized as the best means of controlling the codling moth. The object, as noted elsewhere, is to poison the young larvæ before they enter the fruit. The larvæ get the poison while feeding on the leaves, or in the calyx, or on the sides of the fruit, and are killed. There are several of the arsenical compounds upon the market, and others which the fruit grower can prepare himself. The most available and best are described below.

Paris green.—Paris green is probably the best known of these arsenicals. It is a definite chemical compound of arsenic, copper, and acetic acid, and should have a uniform composition. It is a rather coarse powder, and has the fault of settling rapidly. It costs about 20 cents a pound, but varies in price from year to year with the fluctuation in the cost of the ingredients. It may be prepared for spraying as follows:

Paris green.....	pounds..	1
Lime.....	do....	3
Water	gallons..	150

The lime should be fresh and should be slaked in quantities as required. Mix the Paris green with a little water until a paste is formed, and then add this to the required amount of water, to which the lime has been added. A good average strength to use is 1 pound to 150 gallons, but it must be weaker on trees with delicate foliage. Many fruit growers are using it on apple trees as strong as 1 pound to 100 gallons, but injury to foliage often results.

Scheele's green.—Scheele's green is similar to Paris green, but differs from it in lacking the acetic acid. It is a much finer powder than Paris green and more easily kept in suspension, and it costs only about one-half as much. It is employed in the same way as Paris green.

Arsenate of lime with soda.—In the preparation of this insecticide the following formula may be used:

White arsenic	pounds..	1
Sal soda (crystal)	do....	4
Water	gallons..	1

The above ingredients are boiled until dissolved, which will be in a very few minutes, and the water lost by evaporation is then replaced. To 40 or 50 gallons of water a pint of this stock solution and 3 to 4 pounds of freshly slaked lime are added. This excess of lime is always desired by fruit growers, as they can then see by the amount and distribution of the lime on the foliage how well the spraying has been done. This formula has been thoroughly tested and has been found to be not only as efficient as the other solution, but far cheaper.

Precautions to avoid poisoning.—At all times the greatest care should be taken to prevent accident with these compounds, which are of the most poisonous nature. All packages, boxes, or bottles containing these materials should be plainly labeled and kept under lock. The utensils with which the mixtures are prepared should be thoroughly cleansed after use.

The method of application, spraying dates, and the apparatus to be used are discussed together for both the codling moth and the apple scab on pages 18–23.

APPLE SCAB.

LOSSES DUE TO APPLE SCAB.

Apple scab is perhaps the most destructive fungous enemy of the fruit grower in the northeastern quarter of this country, occupying among diseases a position ranking with that of the codling moth among the insect foes of the apple. Its injuries are greater than are generally appreciated, both in effect and extent. The yield of fruit per tree is greatly lessened whenever scab is present: (1) By the premature dropping of young apples, due to the attacks, soon after the blossoms fall, of the scab fungus on flowers, stems, and fruits; (2) by the smaller size of the scabby apples that mature, and (3) by the loss, just before picking, due to the fact that scabby fruit does not cling well to the tree and is more easily blown off; (4) the value of the fruit harvested is greatly diminished, since spotted apples must be placed in a lower grade and sold for less than clean fruit; (5) their keeping quality also is impaired, as molds and other fungi which cause decay, such as the pink-rot fungus, gain entrance through the scab spots and increase the loss during storage. Nor is the damage confined to the fruit. The leaves also are attacked by the fungus, and the resultant spotting and distortion considerably lessen the vigor and general health of the tree.

The aggregate loss from scab is enormous, amounting to many millions of dollars every year. This is a most oppressive tax on the farmer, since it is unnecessary. An effective remedy is available in Bordeaux mixture. The experience of many years has demonstrated that the loss from scab may be almost entirely prevented by thorough and timely spraying, which is considered by the leading fruit growers throughout the country to be an indispensable orchard practice.

CAUSE.

Apple scab is caused by the summer or conidial stage of a fungus.^a This fungus attains its perfect form^b on dead apple leaves. The disease appears first on the leaves shortly after they unfold, the first infections

^a *Fusicladium dendriticum* (Wallr.) Eckl.

^b *Venturia inaequalis* (Cke.) Ader.

having come from spores blown by the wind from the dead leaves of the previous season. The olive green, velvety spots on the leaves and fruit produce great numbers of spores, which continue to spread the scab broadcast. In a wet season the flowers and very young fruit and its pedicels are attacked. The fungus grows in this manner throughout the summer and autumn. In late autumn and winter the *Venturia* or perfect stage is produced on the dead apple leaves on the ground.

The relative severity of the disease is influenced by a number of factors, chief of which is the weather. A low temperature and abundant moisture favor the development of the fungus, and consequently scab is worse in cool, damp seasons.

Cultural conditions in the orchard influence the scab fungus as much as they do the codling moth. Neglected, unpruned, and uncultivated trees are more subject to scab, and careful attention to the general condition of the orchard in connection with spraying will always be profitable.

Varieties of apples differ in their susceptibility to scab, but susceptible varieties often possess counterbalancing desirable qualities which lead to their extensive use.

HOW TO MAKE AND USE BORDEAUX MIXTURE.

For spraying apples, the following is a formula which has given good results:

Copper sulphate (bluestone)	pounds..	4
Lime.....	do....	5
Water	gallons..	50

When the apple scab is bad and the season wet, 5 pounds of the copper sulphate should be used.

The following paragraphs on making and using Bordeaux mixture and on types of spray outfits are quoted from a recent bulletin prepared in the Bureau of Plant Industry:^a

Method of Making Bordeaux Mixture in Small Quantities.

Where only a small quantity of Bordeaux mixture is required—from a bucketful to a barrel—the method described by Dr. B. T. Galloway in *Farmers' Bulletin* No. 38 gives excellent results. Two half-barrel tubs are made by sawing a barrel through the middle. One tub is used for the bluestone solution and the other for the milk of lime, and each tub should contain 23 to 25 gallons. One man dips the bluestone solution with a bucket and pours it into a barrel or other vessel, and another man simultaneously dips up and pours in bucketfuls of the milk of lime (fig. 3). The lime solution should be kept well stirred. If only a single barrel is to be made, the materials may be dissolved in the dilution tubs;

^a *Farmers' Bulletin* No. 243.—Fungicides and Their Use in Preventing Diseases of Fruits. By M. B. Waite, pathologist in charge of investigations of diseases of fruits.

but if a number of lots are required, the materials can be kept in stock solution (see p. 17) and simply transferred by dipping. In preparing very small quantities of Bordeaux mixture, buckets or similar vessels may be substituted for the half-barrel tubs. It is possible for a single operator to dip a bucketful of the bluestone

solution and then a bucketful of milk of lime and pour them together into a vessel. It is usually preferable to have a bucketful or so of water in the receptacle into which the solutions are to be poured, but this is not essential.

The better and quicker way of making up Bordeaux mixture by the barrel consists in placing the two half-barrel tubs on an elevated platform and then, by means of hose or spigots, allowing the two



FIG. 3.—Men pouring together milk of lime and bluestone to make Bordeaux mixture.

solutions to flow together into a barrel. This method is more fully described farther on.

Straining the materials.—No matter what quantity of mixture is to be made up, it is necessary to strain the materials through a wire strainer. The best type of strainer is made of brass wire with 18 or 20 meshes to the inch. If all the copper solution is strained and then the milk of lime is strained into the dilution vessels, it will not be necessary to strain the Bordeaux mixture, as, on account of its flocculent character, it is sometimes more difficult to pass through the strainer than the lime milk. Some very good strainers made of copper are on the market and may be obtained from the makers of spray pumps. One of the best, which can be made at home, is in the form of a box about a foot square (fig. 4), the bottom of which is a rather heavy board (preferably of hard wood), with a hole bored through it, into which a piece of gas pipe $1\frac{1}{2}$ to 2 inches in diameter and 8 to 12 inches long is fitted. The box is of course open at the top. Fitting just inside this box is a second and lighter box, also open at the top, and having an overhanging strip nailed around the top which supports it. The bottom of this inner box should be made so as to slope at an angle of about 30° , and should be made of wire screen. The slanting bottom makes it harder to clog with the spray, and the inner box, being movable, can be inverted and washed in a tub of water.

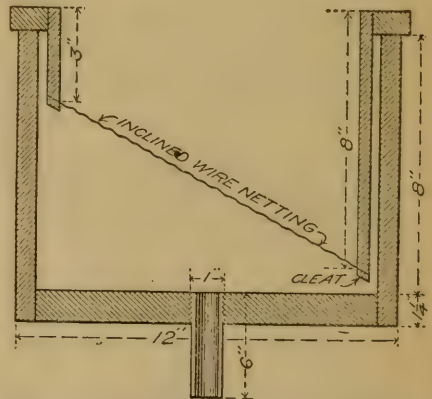


FIG. 4.—Cross section of strainer for Bordeaux mixture.

Method of Preparing Bordeaux Mixture for Large Operations.

In large operations stock solutions should always be used, as the time required to dissolve the material is saved.

Stock solutions.—These can be prepared of both the copper sulphate and the lime. They may be made by dissolving copper sulphate in water at the rate of 1 pound per gallon, and lime in the same ratio, although a strength twice as great may be used in warm weather. When stock solutions are on hand it is only necessary to measure off the required quantity of each and dilute with water before mixing. In preparing a stock solution of copper sulphate, a 50-gallon barrel may be filled about two-thirds or three-fourths full of water; then a sack, or a box with perforations over which copper wire has been tacked, containing 50 pounds of bluestone, should be suspended in the upper part of the barrel and enough water added to fill the barrel. In from twenty-four to thirty-six hours this material will be entirely in solution, and the sack or box may be removed. A slight stirring will insure the even distribution of the bluestone, after which the solution is ready for use.

The copper sulphate should be measured in a copper or granite-ware receptacle, iron or tin vessels being quickly destroyed by either copper sulphate or Bordeaux mixture.

Use of an elevated platform.—If possible the dilution tank should be raised so high on an elevated platform that the mixture can be conducted by gravity directly into the spray tanks beneath (fig. 5). If a hillside is available, it is much the most convenient place to do the work. The platform can be arranged with a roadway on its upper side so that the lime and bluestone can be delivered there, while the spray tank is filled from the lower side.



FIG. 5.—Platform with elevated tanks for making Bordeaux mixture.

The water supply.—A water supply of some sort is necessary; a tank filled by a windmill pump and elevated so as to be a few feet above the dilution tanks is a great advantage. Hose may be used to fill the dilution tanks, or an iron pipe with a spigot may be placed over each tank. Each dilution tank should hold half the quantity it is desired to make up at one time—that is, if a 200-gallon spray tank is to be filled the dilution tanks must hold about 100 gallons each. There is no objection to adding a few extra gallons of water, but it is better to have the tanks hold just the right quantity.

Methods of mixing the solutions.—Either of two methods of mixing can be employed: One in which the spray material is conducted directly from the dilution tanks into the spray tank and actually mixed in this tank; the other in which a mixing tank sits just below the dilution tanks and from which the spray, after being mixed up, is conducted by gravity into the spray tank. In certain ways the latter is more convenient than mixing directly into the tank, but unless the operations are somewhat extensive it will hardly justify the extra expense. In very large operations, however, a separate mixing tank is recommended—or perhaps even two of them side by side—so that batches of the mixture can be kept on hand for a few moments awaiting the spray wagons.

Testing Bordeaux Mixture.

When Bordeaux mixture is properly prepared it is of a brilliant sky-blue color. If the lime is air slaked or otherwise inferior in quality, resulting in a bad mixture, the preparation will have a greenish cast, and if this is very pronounced the mixture will injure the foliage.

In order to make certain that the copper sulphate is properly neutralized by the lime, the yellow prussiate of potash test may be used. A small bottle containing a 10 per cent solution of yellow prussiate of potash can be secured from a druggist. After stirring the Bordeaux mixture, a drop of this solution is allowed to fall on the surface of the preparation. If free copper is present, the drop will immediately turn reddish-brown in color. Lime should then be added until the brown color fails to appear. If the reaction is complete, the yellow prussiate of potash solution will remain a clear yellow until it disappears in the mixture.

SPRAYING.

TYPES OF SPRAY OUTFITS.

The barrel pump.—No type of spraying outfit is more widely used or has given better satisfaction in small or medium-sized commercial plantations than the barrel pump (fig. 6.) A great many different forms are now supplied by the makers of spray pumps, and a number of them are efficient and successful. They are mounted in a great variety of ways. An ordinary 50-gallon whisky or kerosene barrel forms an excellent and inexpensive tank for holding the spray. The pump, according to its design,

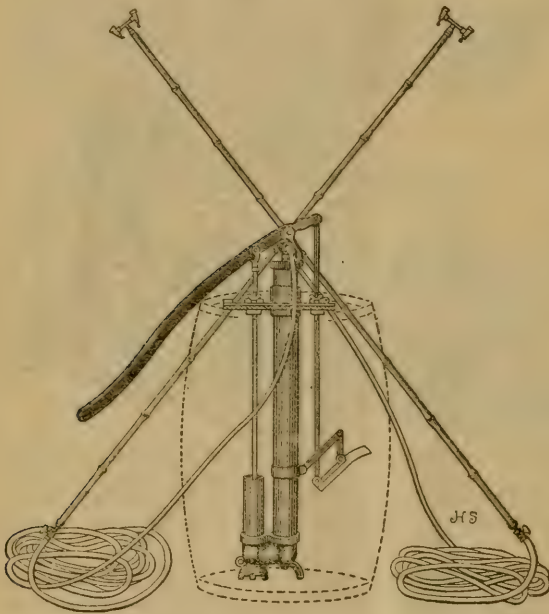


FIG. 6.—Barrel spray pump.

can be inserted in the end or the side of the barrel. The barrel may then be mounted to suit the operator on a sled or on two wheels, or it may be placed in a cart or wagon. A small sled can be made in a few minutes by spiking some plank across a couple of pieces 2 by 4 inches, or, better, 3 by 4 inches, with the ends rounded to serve as runners. Such an outfit can be drawn through narrow rows of vegetables or other crops, where a wagon could not go. The ordinary 2-wheeled cart makes a very convenient rig to use with the barrel sprayer. One man can easily drive the cart and pump while one or two additional hands can apply the spray from the ground.

The tank outfit.—Various forms of tanks can be mounted on a two-horse wagon and thus enable a larger quantity of spray to be carried into the field. These tanks are sometimes square or rectangular. Some orchardists prefer to mount a large hog-head, either end up or on its side, and to pump the spray from that. As a rule, however, the best style is either a rectangular tank or a half-round tank, flat on top.

With the rectangular or half-round tank an ordinary barrel pump can be used, but it is much better to use one of the larger tank pumps especially made for the purpose (fig. 7). This can be mounted either on top of the tank or on a platform at either end. The regular tank pump has a suction of whatever length is desired, which draws the spraying mixture from the tank. One of the great advantages of the tank-pump outfit is the convenience of arranging an elevated platform. Where tall trees are to be sprayed it is almost impossible to reach the tops from the ground with extension rods of reasonable length. A scaffolding or tower of the height desired can be built on top of the wagon, and the operator can thus be elevated 10 or 12 feet from the ground. A type of the tank-pump outfit is shown in the accompanying illustration (fig. 8).

Geared sprayers.—In the above-described outfits the pressure on the pump is secured by man power. Ingenious fruit growers, as well as manufacturers, have devised several contrivances by which power is obtained by means of a sprocket wheel from the axle of the wagon. There are a number of different devices, several of which are more or less successful. As a rule these geared devices are better adapted to low-growing crops, like potatoes and strawberries, and possibly also to vineyards, than they are to large orchard operations, although they have been used a good deal in orchards. In spraying fruit trees the operator frequently stops long enough to coat each tree thoroughly before proceeding. Usually this can not be done with the geared sprayers, although some have provision for storing up the pressure.

Steam and gasoline outfits.—The highest type of spraying outfit consists of a steam, gasoline, or kerosene pump mounted on a wagon and drawing the liquid

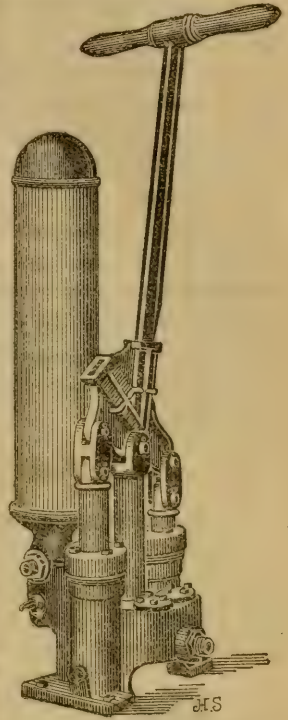


FIG. 7.—Large hand spray pump.

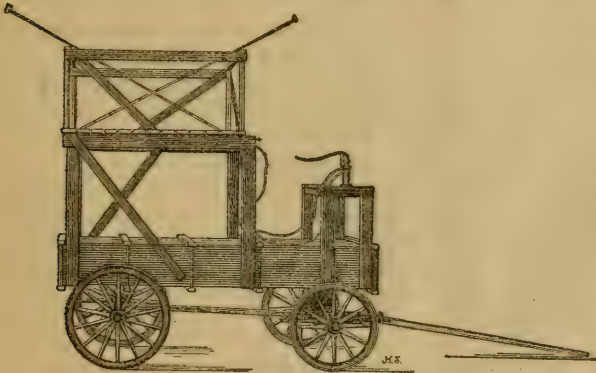


FIG. 8.—Tank outfit with hand pump.

from a tank holding 100 to 300 gallons. Several growers use very successfully a small 2 or 3 horsepower steam boiler and a bronze steam pump. This is carried on a platform on the wagon. The only objection to such an outfit is its weight, but, on the other hand, those who have used steam sprayers seem to have less fault to find than the users of the gasoline sprayers.

Recently the writer has used a very successful kerosene outfit very similar to the one described above. With a gasoline or steam outfit it usually pays to have four leads of hose and four men spraying at a time.

SELECTION OF SPRAY OUTFITS.

In selecting spray pumps from catalogues, the number and size of the trees are the principal factors to be considered.

For home orchards of small size a good equipment consists of a hand barrel pump, 15 feet of $\frac{3}{8}$ -inch hose, one 8-foot bamboo extension rod, one double Vermorel nozzle; cost of outfit, \$12 to \$18.

For a medium-sized orchard choose a slightly larger pump of the same pattern (fig. 6), and equip it with two lines of hose, two double Vermorel nozzles, and two bamboo extension rods; cost, \$25 to \$30.

For a large orchard, exceeding 1,000 trees in bearing, select a double-cylinder pump of large capacity (fig. 7), operated by an upright lever. Four to six leads of hose can be supplied in this way. Such an outfit, including a 200-gallon tank, costs from \$75 to \$90.

For still larger operations more expensive power sprayers are recommended.

THE HOSE AND EXTENSION RODS.

The following paragraphs are reprinted from Farmers' Bulletin No. 243:

Nothing contributes more to success in spraying operations than satisfactory hose and nozzles. In ordinary spraying operations with the barrel pump, half-inch hose is commonly used. As a rule, however, for the barrel pump three-eighths or one-fourth inch hose is better. The lighter hose is easier to handle and is less likely to kink and break. Good three-ply or four-ply hose in either case should be bought. It usually does not pay to attempt to use cheap hose in spraying. The couplings should be of a style readily adjusted in the field by means of a screw-driver, and everything must be kept tight to withstand pressure, especially in case of the power outfits.

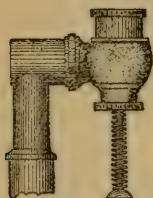


FIG. 9.—Vermorel spray nozzle.

The ends of the hose should be attached to extension rods of suitable lengths for the work. (See fig. 6.) Occasionally in getting up a very cheap outfit one-fourth-inch iron gas pipe may be used. It is heavy and clumsy, however, and is only a temporary expedient at best. For all lengths above 6 feet a bamboo extension rod is recommended. This consists of a small brass tube supported by a bamboo rod.

The most important part of the whole apparatus is the nozzle. Unfortunately this feature has been much neglected by pump manufacturers, and many inferior nozzles have been sent out to farmers. There is a tendency to improvement in this direction in the past two years, however. Good results in the application of the spray mainly depend upon the efficiency of the nozzle. For most purposes the best nozzle is the Vermorel or a nozzle of that type (fig. 9).

METHOD OF SPRAYING.

Thorough work essential.—It is most important that spraying should be done thoroughly. Most of the failures are due to careless work. The whole surface of every bud and leaf should be covered. Any por-

tion left unsprayed is subject to the attack of the scab fungus or may allow a codling-moth larva to escape.

Overspraying to be avoided.—The operator should endeavor to deposit the spray in the form of a fine mist, covering the leaves with small drops, and should be careful to stop at this point, viz, before the mixture collects in larger drops and drips from the tree. Less will be left on the leaves if the spraying is continued too long and an unnecessary amount of the mixture is used.

COST OF SPRAYING.

The cost of spraying varies so greatly under different conditions that only approximate figures can be given. The varying factors are the wages and efficiency of the labor employed, the capacity of the spraying outfit (the work can be done cheaper with a large outfit than with a small one), the size and condition of the trees, the conveniences provided for preparing and holding the mixture, the nearness to water, etc., and, lastly, the cost of materials.

The cost of the different arsenicals varies rather widely. Lime arsenite with soda is cheapest, its cost being little more than one-quarter that of either Paris green or lead arsenate and about one-half that of Scheele's green. The fruit grower can judge for himself whether it is worth his while to go to the trouble of home preparation of the cheaper arsenicals.

Bordeaux mixture prepared fresh at home is both cheaper and more effective than the ready-made article. The farmer should by all means make his own mixture. Bluestone fluctuates in price, but is obtainable in moderate quantities for about 7 cents per pound.

Materials for spraying 100 trees with Bordeaux mixture and arsenicals can be had for from \$2 to \$3. The cost of application is likely to exceed the cost of the materials. Records of the actual expense incurred in spraying orchards vary from 5 cents to 30 cents per tree for the entire season's work of three to six sprayings.

SPRAY INJURY TO FOLIAGE OR FRUIT.

No injury should result from the sprays recommended in this bulletin if properly prepared and applied, though such injury is occasionally reported to occur under unusual weather conditions or when mistakes have been made. This is indicated by the burning of the leaves, especially of the tips and margins, and a russetting of the fruit. To avoid this injury, follow directions exactly. Take special care to have the lime pure and freshly slaked. An excess of lime will do no harm and should be used if any spray injury is observed. Do not use more bluestone or arsenical than advised.

WHEN TO SPRAY FOR THE CODLING MOTH AND THE SCAB.

It is practicable to combine most of the sprayings for the codling moth and apple scab and thus lessen by one-half the cost in time and labor. The arsenical may be added to the diluted Bordeaux mixture at the same rate as to pure water, and the lime in the Bordeaux mixture will act as an additional preventive of scalding from the arsenical and obviates the necessity of adding lime to take up free arsenic. The dates of spraying for the first brood of the codling moth and for the apple scab are the same except for the first treatment for the scab, which should be made after the leaf buds unfold but before the flower buds open, and is the most important application for this disease. The arsenical in this first application has no relation to the codling moth, which has not yet appeared, and it is sometimes omitted; but its addition costs very little, and it will reach the canker-worm, bud moth, and curculio. The subsequent sprayings apply to both the codling moth and the apple scab, and the arsenical should always be added to the Bordeaux mixture. The second spraying should be made just after the blossoms fall and before the calyx closes, and is the most important of the sprayings for the codling moth, getting the poison into the open calyx, where it will subsequently destroy the larvæ before the latter can penetrate into the apple. The third spraying should follow in seven or eight days, and the fourth three weeks later. In the case of the codling moth these destroy the young caterpillars on the leaves before they reach the fruit and in their feeding about the calyx, and assist in the control of apple scab. A fifth combined spraying may be given thirty days subsequent to the fourth, but this is optional in the case of both pests and will depend on the amount of probable infestation of either codling moth or apple scab.

Later sprayings against the codling moth are directed against the larvæ of the second generation when they are entering the fruit, and need not be combined with the Bordeaux treatment for the scab. The time for this spraying for the codling moth will vary with locality and seasons. The larvæ of this second generation enter the fruit beginning with the last of July and extending through August and September. The number of sprayings to be made against this second generation depends upon the efficiency of the preventive measures and of the early sprayings. Two of these later sprayings are usually sufficient, and may be made, respectively, during the last week in July and about the middle of August. The quantity of lime used in the last spraying should be reduced to not more than 1 pound to the pound of arsenical to avoid a limy coating on the ripe fruit.

Light showers have but little effect in washing away the spray, but a continued rain or heavy shower may make it necessary to repeat the application.

SPRAY CALENDAR.

For the convenience of orchardists and others, the materials to be used at each spraying and the times for applying the same to secure the best results have been arranged in the following tabular form:

Number of appli- cation.	Material.	Time of application.
First.....	Bordeaux mixture and arsenical.....	After leaf buds unfold and before flower buds open.
Second	Bordeaux mixture and arsenical.....	Just after petals fall.
Third.....	Bordeaux mixture and arsenical.....	7 or 8 days later. (This may be omitted in dry seasons, and in dry States like Nebraska.)
Fourth	Half-strength Bordeaux mixture and full-strength arsenical.	8 weeks later.
Fifth	Half-strength Bordeaux mixture and full-strength arsenical.	30 days later (optional).
Sixth	Arsenical.....	July 25.
Seventh	Arsenical.....	August 15.

The first and second applications are the most important in controlling apple scab, and the second and fourth are most important in combating the first brood of the codling moth. The third and fifth are optional for both pests as indicated, and the sixth and seventh are for the second brood of the codling moth only, and have no relation to the scab.

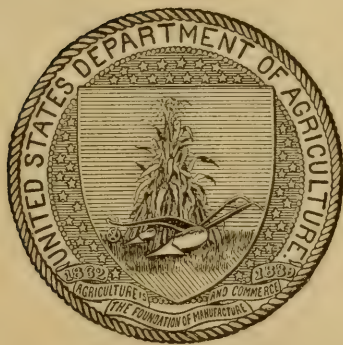
U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 264.

THE BROWN-TAIL MOTH AND HOW TO CONTROL IT.

BY

L. O. HOWARD,
ENTOMOLOGIST.



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1906.

LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., August 30, 1906.

SIR: I have the honor to transmit a brief account of the brown-tail moth (*Euproctis chrysorrhæa*), with some consideration of methods of control, which I believe is suited for publication as a Farmers' Bulletin.

Very respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE BROWN-TAIL MOTH AND HOW TO CONTROL IT.

INTRODUCTION.

The brown-tail moth (*Euproctis chrysorrhæa* L.) is a European moth of the family Liparidæ, accidentally introduced into New England about fifteen years ago, and which has rapidly spread until at the present time it covers a large extent of territory and threatens still further rapid spread. It is an injurious enemy of orchard, forest, and shade trees and of ornamental shrubbery. It is being strenuously fought in Massachusetts under a large appropriation devoted to its suppression and to that of the gipsy moth (*Porthetria dispar* L.). The other New England States in which it occurs are also beginning or about to begin the enforcement of remedial measures, and much intelligent work has been done by communities in the State of Maine during the past year. During the last session of Congress a sum of money was appropriated to be expended under the Bureau of Entomology in preventing the further spread of the gipsy and brown-tail moths, and it is in furtherance of this end that the present bulletin is published. Actual antispreading work can be done to advantage against the gipsy moth, since the female of this insect does not fly and the species is spread only in the larval or caterpillar stage, when it spins down from roadside trees and alighting upon some vehicle or person is thus carried for long distances. With the brown-tail moth, however, the case is entirely different. As will be shown, the female flies readily and is carried during its period of flight by the prevalent winds for very long distances. It is therefore much more difficult to prevent the spread of this insect than of the other, and in fact the only effective measures are those of actual work in the extermination of the insect wherever it occurs. To attempt such work as a Government measure and with the funds appropriated by Congress would be futile. It is safe to say that to effectively check the further spread of the brown-tail moth would require its complete extermination; and to bring this about millions of dollars would have to be spent. Plainly the thing to do, therefore, with regard to the brown-tail moth, is to secure the active and intelligent cooperation of all property holders thruout the infested district. This must be done primarily by a campaign of

education. Then communities must take the matter up thru town-improvement societies and organizations of other character, and, best of all, sound State laws comparable to the one now operating in the State of Massachusetts must be enacted and enforced in the other States. This bulletin is prepared to aid in the first step—education. Other bulletins have been issued by the Superintendent for Suppressing the Gipsy and Brown-Tail Moths in Massachusetts, by the Commissioner for the Suppression of the Gipsy and Brown-Tail Moths in Rhode Island, and by the State entomologists of New Hampshire, Maine, and Connecticut. All of these bulletins^a have been published within the last eight months.

The subject has also been covered by the New York State entomologist, Dr. E. P. Felt, of Albany, N. Y., and by the New Jersey State entomologist, Dr. John B. Smith, Rutgers College, New Brunswick, N. J. These last two publications are in annual reports, together with a consideration of other insects, and are not specific bulletins, as in the case of the others.

THE BROWN-TAIL MOTH IN EUROPE.

The brown-tail moth has a wide Old-World distribution. It has for many years been a well-known member of the so-called Palearctic fauna. It extends from England east to the Himalayas, and has been found as far north as Sweden and as far south as Algeria. It is well known as an orchard pest thruout the greater part of this range, and has occasionally appeared in such numbers as to attract general attention. For nearly a hundred years laws have been operative in parts of Europe requiring property owners to clear their trees of the winter nests. The life history of the insect has been well known in Europe for about two hundred years, has been the subject of many publications, and is referred to in most of the general works.

INTRODUCTION INTO AMERICA AND SUBSEQUENT SPREAD.

The attention of entomologists was first drawn to the occurrence of this species in the United States in the spring of 1897, when certain residents of Somerville and Cambridge, Mass., found a strange caterpillar feeding on the unfolded leaves of their pear trees. The attention of the State of Massachusetts gipsy moth committee was called

^a Persons desiring to consult these publications may apply to the following officials:

Mr. A. H. Kirkland, 6 Beacon street, Boston, Mass.

Prof. A. E. Stene, Kingston, R. I.

Prof. E. Dwight Sanderson, New Hampshire College, Durham, N. H.

Prof. E. F. Hitchings, Augusta, Me.

Miss Edith M. Patch, Agricultural Experiment Station, Orono, Me.

Prof. W. E. Britton, Agricultural Experiment Station, New Haven, Conn.

to the matter during that year, and the identity of the form with the well-known European species was determined by Messrs. Fernald and Kirkland.

An investigation was at once made as to the probable time and method of introduction. The fact was established that the moth had been in Somerville for several years previous to 1897, gradually becoming acclimated and slowly spreading outward into noninfested territory. The balance of evidence seems to indicate that the species was probably introduced from Holland or France upon rose bushes imported by a florist in Somerville about 1890.

Down to 1897 the spread of the insect had evidently been slow, but the danger was imminent, and during the spring of that year the writer, together with a representative body of Massachusetts agriculturists and officials, appeared before the governor of the State and urged the passage of an appropriation bill providing means for its extermination. Six thousand dollars was appropriated by the legislature to be expended by the gipsy-moth committee of the State board of agriculture. Careful examination showed that at that time fifteen towns were infested, the insect being found upon 2,226 estates. As much as could be done was done under the appropriation, and a certain amount of work was carried on during the following two years. Then all State appropriations were stopt, both against this insect and the gipsy moth, and for five years the insect spread unchecked except by the work done by individual property holders and town-improvement societies.

In 1899, when the work stopt, an area of approximately 928 square miles was infested, extending from the ocean along the New Hampshire line to the western border of the town of Methuen, thence practically directly southward to Newton, and thence the limiting border extended gradually in a southeasterly line to Cohasset, including the entire suburbs of Boston. In 1903 a report was published by the State of Massachusetts, under the authorship of C. H. Fernald and A. H. Kirkland, giving a full account of the insect and indicating that between the autumn of 1899 and that of 1902 nearly 600 square miles of territory had been added to the American range of the species, which had spread out to Kittery, Me., and had included a large portion of southeastern New Hampshire. One occurrence at St. John, New Brunswick, was reported also.

By the close of 1905 the two lower tiers of counties in New Hampshire had become generally infested, and specimens had been sent in to the State entomologist of New Hampshire from the White Mountain region. Notable flights of the moths had been observed at Nashua, Concord, and Portsmouth. In Maine the insect had been found scattered along the coast at various places—Portland, Rockland, and

Augusta were generally infested; the insect had appeared in considerable numbers on the island of Mount Desert; and had been reported at Eastport. A single finding also had been reported at Providence, R. I., but the insect had not been found in the State of Connecticut. In Massachusetts there had been a wide spread to the southward and a slower spread to the westward, the species having been found as far east as Amherst. Full reports have not been made of the additional spread during 1906, nor will it be possible accurately to make such reports until the leaves fall in the autumn and the winter nests are readily to be seen.

DESCRIPTION OF THE INSECT.

The eggs.—The eggs of the brown-tail moth are small and globular, and are laid in masses on the underside of leaves in the latter part of



FIG. 1.—The brown-tail moth (*Euproctis chrysorrhæa*): Female moth above, male moth below, larva or caterpillar at right. Slightly enlarged (original).

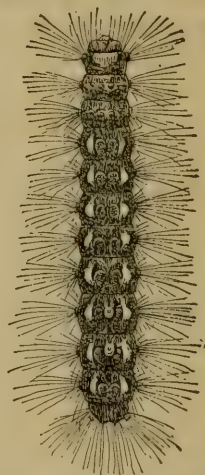


FIG. 2.—Caterpillar of the brown-tail moth. Enlarged (from Fernald and Kirkland).

July. The egg masses are brown in color and are covered with hair, each mass containing about 300 eggs. They are much smaller than the egg-masses of the gipsy moth, with which they are most likely to be confused, and average about two-thirds of an inch in length by about one-fourth of an inch in width. They are thus elongate in form, and are convex.

The larva or caterpillar.—The full-grown larva (fig. 1 at right; fig. 2) is about 2 inches long, reddish brown in color, with a broken white stripe on each side and two red dots on the back near the hind end. It carries also patches of orange and is covered with tubercles bearing long barbed hairs. The tubercles along the back and sides are covered

with short brown hairs in addition to the longer ones, which give the tubercles when magnified an appearance like velvet. The head of the larva is pale brown with darker mottlings.

The young larvæ are of a blackish color covered with reddish brown hairs. The head is jet black. Close examination will show projecting from the back of the fourth and fifth abdominal segments a large tuft of reddish brown hairs, and on the middle line of the ninth and tenth segments is an orange or reddish tubercle which may be withdrawn into the body. After the second spring molt the larva is about three-eighths of an inch long, the yellow markings on the body are more apparent, and the brown tufts on the back less prominent, while the band of white dashes along the sides, characteristic of the full-grown larva, is noticeable.

The pupa.—The full-grown larva spins a cocoon of grayish silk, which is very loose in its construction and is so far from being compact that the pupa may be readily seen thru it. The pupa itself is about five-eighths of an inch long, dark brown in color, with a conical spine at the end of the abdomen bearing a cluster of minute hooks at the tip. Smooth, yellowish brown hairs are found scattered over the abdomen and the top of the thorax.

The cocoons are apparently spun by preference among the leaves at the tips of branches, and often a dozen or more larvæ will spin a common web within which each individual forms its own cocoon and transforms to pupa. The cocoons are also found under fences and beneath the edges of clapboards. Mr. Kirkland has seen a mass of cocoons nearly 2 feet across in the cornice of a house in Somerville.

The adult or moth.—The moths (fig. 1, at left) are pure white, the end of the abdomen being brownish, and both sexes bear at the tip of the abdomen, more conspicuously with the female, a tuft of brown hairs, almost globular in form, from which comes the name brown-tail moth. It is the only moth occurring in America to which this description applies, and is therefore unmistakable. The female expands about $1\frac{1}{2}$ inches, and the male is smaller.

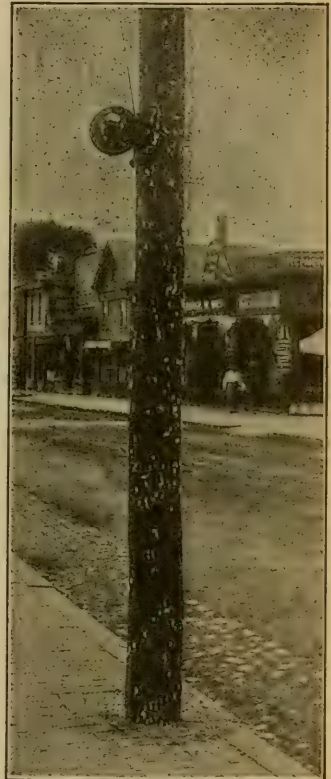


FIG. 3.—Brown-tail moths on electric-light pole, Malden, Mass., July 12, 1905. (From Kirkland.)

SEASONAL HISTORY.

The moths fly in New England from the 1st to the 20th of July, the time varying with the condition of the season. In 1898 the height of the flying season is said by Fernald and Kirkland to have been July 16, in 1899 July 8, and in 1902 July 14. It is a night-flying insect, and only a few are ever seen on the wing in the daytime. Soon after sunset a few begin to fly, the number increasing as it grows dark, and from

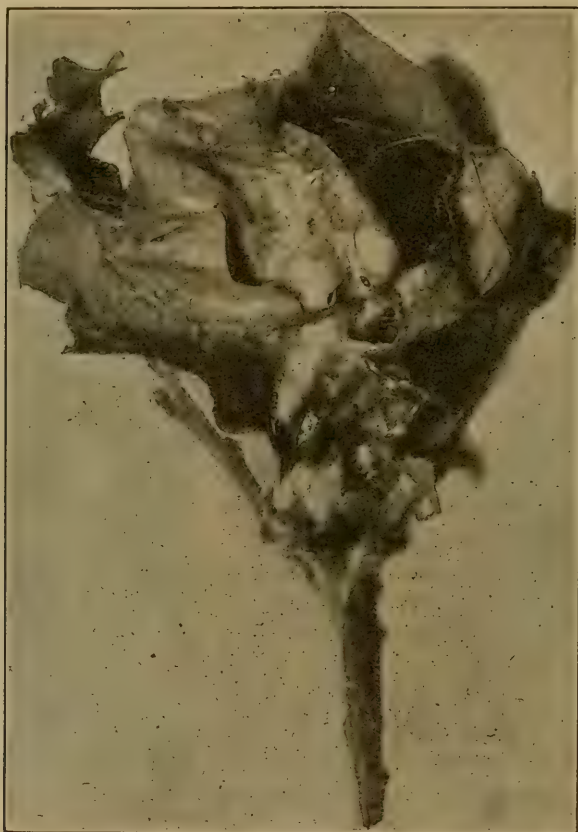


FIG. 4.—Winter web of the brown-tail moth. (After Kirkland.)

10 o'clock to midnight they swarm to the greatest extent. They are strong flyers, and are attracted to light (see fig. 3). So great have been their numbers in the infested region that the sides of red brick buildings near electric lights have appeared perfectly white. It is at this time that the great spread of the species occurs, and the reason that the direction of the spread has been greatest toward the northeast has been the fact that the prevalent night winds at that time of the year seem to have been from the southwest. Aside from actual flight, the

species has spread by being carried in the moth condition on railway trains and on vessels. Captains of vessels have reported that the moths have alighted upon their ships in great numbers in the vicinity of Boston along toward midnight on several occasions, and the introduction of the species at more than one seaport in Maine has been by means of vessels coming from the infested district rather than by direct flight. Of course the brown-tail moth is carried in the caterpillar stage just as is the gipsy moth, upon vehicles of different kinds passing thru the infested region and upon the persons of pedestrians as well. In late May, 1906, the writer, in company with three other persons, walked thru the woods in a region not far from Boston, and altho the most careful efforts were made by each of us to pick the caterpillars from the clothes of the others, an hour or two afterwards and many miles away by automobile still others were found under the upturned trousers and lapels of coats and in other hidden places about garments.

The eggs are laid by the moths soon after the flight begins, say in the latter part of July. They hatch during August and the young larvæ feed in clusters on the upper surface of leaves, skeletonizing them and causing the foliage to turn brown as if blighted. At first they feed upon the leaf which bears the egg mass, but soon wander to others, returning at night to the original leaf. When first hatched they are about one-twelfth of an inch long, and in five to six days shed their skin, increasing in length to one-fifth of an inch.

Later the second molt occurs, altho this sometimes does not take place until autumn within the winter web. Along in September they begin to spin their winter webs by drawing together a number of leaves with silk, and in each of these nests a large number of caterpillars stow themselves away for the winter. These webs or nests, composed of leaves and silk, will average from 5 to 6 inches in length, and each will contain 200 or more caterpillars. The caterpillars feed until cold weather, and then all enter the web and close the exit holes. They are then about one-fourth grown.



FIG. 5.—Web of the brown-tail moth. (After Kirkland.)

These winter webs (figs. 4-7) of the brown-tail moth are very characteristic, and there are practically no other insect structures common upon trees which may be mistaken for them. There are certain old webs of native species which might possibly, by the untrained eye, be considered to be those of the brown-tail moth, but these are empty



FIG. 6.—Winter webs of the brown-tail moth, attached to fruit. (After Kirkland.)

in the winter time. Any web of this character and general size found during the winter which contains young caterpillars in any number is the web of the brown-tail moth.

The following spring, as soon as the buds begin to appear upon fruit trees, these young, one-fourth-grown caterpillars issue from the overwintering nests and attack first the buds and blossoms and later the foliage. Apparently half starved by their long hibernation, they

come out with voracious appetites, and the amount of damage done by them at this time is extraordinary. Old trees may lose all their buds, or, if the leaf buds and blossom buds burst, the foliage itself may



FIG. 7.—Winter webs of the brown-tail moth on pear tree, Melrose, Mass., December, 1905. (After Kirkland.)

be entirely destroyed at a later date. The growth of the larva is rapid, and it reaches full size and begins to spin its cocoon during the last half of June, transforming to pupa and remaining in this condition for approximately 20 days.

DAMAGE TO PLANTS.

As just indicated, the damage to trees and shrubs may be very severe. The list of food plants is very extensive. While there seemed at first to be a preference for pear (figs. 7, 8) and apple, the larvæ were found to feed also upon the stone fruits, as well as upon the elm, maple, and several species of oak. Of late years there has been a very extensive infestation of scrub oak and of the larger trees of the genus *Quercus*. In fact the caterpillars feed generally upon all deciduous trees, on many shrubs, and even upon herbage. A list of over 80 different food plants was published by Fernald and Kirkland in



FIG. 8.—Pear trees stript by the brown-tail moth, Winchester, Mass., June 9, 1905. (After Kirkland.)

1903. Thousands of fruit trees in the vicinity of Boston have been killed by this insect. Injury to woodlands and forests has not been as severe as that accomplished by the gipsy moth, and coniferous trees do not seem to be attacked, but the damage to oak, maple, and elm in the wooded region has been sufficient to cause the forests to appear brown in June in places, and complete defoliation for a series of three or four years has brought about the death of many trees. Even where the tree survives, its growth has been checked, and there is a timber loss.

BROWN-TAIL RASH.

The term "brown-tail rash" is well understood in eastern New England at the present time, although a few years ago it was practically unknown. The hairs of the brown-tail caterpillar are finely barbed and brittle (see fig. 9), and where the caterpillar comes in contact with the human skin these hairs enter the skin pores, break off, and cause a



FIG. 9.—Hairs of the caterpillar of the brown-tail moth, highly magnified. (Adapted from Kirkland.)

severe irritation. Indeed, it is not necessary for the caterpillar itself to come in contact with the skin; at certain times of the year it seems as though the hairs were actually floating about in the air. At the time of the caterpillar's change of skin, and particularly at the time of the spinning of the cocoon and the final change, certain of these hairs

appear to become loosened in such a way that they are carried by the wind. A few people have been made seriously ill by this so-called rash, and it is the cause of great annoyance. Extreme cases were noted during the past summer in the parasite laboratory at North Saugus. Two of the assistants who had charge of the American end of the introduction of the European parasites of the gipsy moth and brown-tail moth and were obliged to handle large numbers of the wintering nests brought over from Europe were poisoned to such an extent that their hands and arms were swollen to great size, their eyes were swollen nearly shut, and the irritation of the hairs in the throat and nasal passages was such as to cause alarming symptoms. Beginning with April, one of the assistants has had an almost constant cough from this cause, lasting to the date of the present writing (August 30). Persons engaged in removing the nests from trees in the winter time and in carrying them away to be burned also suffer from brown-tail rash, altho the trouble is not so great in the winter time as in the summer time, since during warm weather the pores of the skin are more open and more receptive to the hairs. A large part of the popular feeling in New England that the brown-tail moth must be exterminated is due quite as much to the prevalence and annoyance of this rash as to the loss of vegetation from the work of the caterpillars.

For a time the free use of vaseline was recommended for the so-called brown-tail rash, but of late cooling mixtures have been used in preference, and an excellent prescription which has been tried repeatedly with good effect is the following:

Menthol	grains..	10
Zinc oxidi	drams..	2
Aq. calcis	ounces..	8
Acid carbolici	drops..	15

This mixture is for external use.

The hairs which produce the worst effect are the short brown ones from the tubercles on the back and sides of the abdomen. They are illustrated in fig. 9. This nettling or urticating effect is not peculiar to the hairs of the brown-tail moth. A number of our native species carry similar hairs. The difficulty is apparently purely a mechanical one, and there is no accompanying specific poison.

NATURAL ENEMIES AND PARASITES.

Observations extending over a number of years show that birds are important in checking the spread of the brown-tail moth. The caterpillars, like other hairy species, are not so much eaten by birds, except by certain ones, such as the yellow-billed and black-billed cuckoos and the Baltimore oriole. The yellow-throated vireo and the bluejay also

feed upon them. When the moths emerge in number, however, they are preyed upon by a great many birds, and even the English sparrow destroys large numbers of them. July 16, 1897, Mr. Kirkland observed whole flocks of English sparrows following along the lines of fences carefully searching for the moths, which when found were greedily devoured. Of course many of these moths will have laid their eggs before they are destroyed, yet the work as a whole counts. Bats and toads also eat the moths as they fly about electric lights, the latter devouring them when they fall to the ground.

Certain of our native parasites which destroy allied insects like the fall webworm and the tussock moth also breed in the brown-tail moth, but the percentage of parasitism is very small.

An effort is being made to introduce the European parasites of both the brown-tail moth and the gipsy moth, and during the past year many thousands of such parasites have been introduced and liberated in the vicinity of Boston. They are first cared for in a laboratory at North Saugus; many of them are afterwards studied under outdoor tents, while still others have been liberated in the open in badly infested woodlands. The results down to the present time are encouraging, but it may be a matter of some years before appreciable results are obtained, and there is a possibility, also, that these European parasites will not multiply to the same extent as in Europe. Therefore active mechanical measures must still be continued, and perhaps for years to come, in the actual destruction of the injurious insect.

REMEDIES.

The most obvious means of controlling the brown-tail moth, and the easiest one, is the collection and destruction of the winter nests after the leaves have fallen. These webs, elsewhere described, are conspicuous from October to April. Many of them are within reach, and as each contains 200 caterpillars or more, each one capable of destroying a number of buds in the spring, the value of this work is at once evident. The webs should be removed before the first part of April. In Massachusetts, on the larger trees, are used long ladders and climbing irons, and some men make a business of destroying these nests upon private estates. The twigs carrying the nests are clipped off with one of the ordinary tree pruners (fig. 10) and the collected nests are burned.

After the leaves come out in the spring the nests remaining on the trees will be empty, and it is no longer worth while to make an effort to collect them. Practically the only remedy after this date is spraying with an arsenical mixture. When they are young the larvæ may be effectively destroyed by spraying with arsenate of lead. They may

also be destroyed by a Paris-green spray, in the proportion of 1 pound to 100 or even 150 gallons of water. A stronger mixture will burn the foliage. Arsenate of lead, however, may be applied much stronger,

and this substance should be used when the caterpillars are larger. Mr. Sanderson, as the result of an experiment in New Hampshire, recommends 5 pounds of arsenate of lead to a barrel of water when the caterpillars are large.



FIG. 10.—Pruning shears suitable for removing the winter webs of the brown-tail moth. (From Fernald and Kirkland.)

Organized efforts have been made in many villages and towns, under the auspices of local associations, to secure the collection and destruction of the nests in the winter. In some cases the services of school children and others have been enlisted by the payment of a small bounty, and very many thousands of nests have been collected and destroyed in this way. Massachusetts is now working under a good State law, a summary of which is published

below. Other States already infested or liable to infestation in the near future should pass similar laws.

THE MASSACHUSETTS LAW.

The following is a summary of the essential features of the Massachusetts law to provide for suppressing the gipsy and brown-tail moths:

The moths are public nuisances.—The gipsy and brown-tail moths are declared public nuisances and their suppression is required.

The superintendent of suppression.—A superintendent appointed by the governor with power, subject to the governor's approval, of appointing agents and assistants has entire general charge of the work of suppressing the moths.

Duties of cities, towns, and individuals.—Cities and towns (under the advice and general direction of the superintendent, and by such agent as they may designate or appoint) are required, under penalty for neglect, to destroy the eggs, pupæ, and nests of the gipsy and the brown-tail moths within their limits, *excepting* that such work is not to be done by cities and towns on property controlled by the Commonwealth, nor is it to be done upon private property, *excepting* where the owners of the same fail to destroy the eggs, pupæ, and nests of the moths, in accordance with the terms of the official notice to private owners noted in the section here following:

Notice to private owners.—The mayor of every city and the selectmen of every town shall, at suitable times, notify every owner of land

located therein which is infested with the moths, requiring him to destroy the eggs, pupæ, and nests of the moths within a specified time.

When the mayor or selectmen decide that the cost of such destruction (on lands contiguous and under one ownership) will exceed one-half of 1 per cent of the assessed valuation of the lands, then they may designate in the notice a part only of such lands on which the destruction shall take place.

Failure of private owners to destroy moths.—If the owner does not, as required by the terms of the aforesaid notice, destroy the eggs, pupæ, and nests of the moths, then the city or town, subject to the approval of the State superintendent, shall destroy them, and shall assess upon such aforesaid lands the actual cost of so doing, to an amount, however, not exceeding one-half of 1 per cent of the assessed valuation of the land.

This amount, so assessed, shall be collected in the form of taxes, and constitutes a lien upon such lands.

Redress by abatement and appeal.—The assessors may abate the moth assessment in the case of any private landowner decided by them to be unable to pay it because of age, infirmity, or poverty.

Appeal to the county superior court, with special provision for prompt hearing, is provided by the statute for any person aggrieved by assessment on account of this work; provided a complaint is entered within 30 days of notice of such assessment.

Appropriation by the Commonwealth.—To meet the expenses incurred under its moth-suppression law the Commonwealth has appropriated \$300,000. Of this sum \$75,000 may be expended during 1905, \$150,000 (and any unexpended balance) during 1906, and \$75,000 (and any unexpended balance) during 1907, up to May 1, 1907, inclusive.

For the purpose of experimenting with natural enemies for destroying the moths, \$10,000 is additionally appropriated for each of the years 1905, 1906, and 1907.

Reimbursements to cities and towns.—(1) Cities and towns with valuation of real and personal estate of \$12,500,000 or more, having spent \$5,000 in any one calendar year, shall be reimbursed annually 50 per cent (one-half) of all further expenditure in combating this pest.

(2) Cities and towns with valuation less than \$12,500,000 and more than \$6,000,000, having spent an amount equal to one-twenty-fifth of 1 per cent of such valuation in one year, shall be reimbursed annually 80 per cent (four-fifths) of all further expenditure.

(3) Towns with valuation less than \$6,000,000, having spent an amount equal to one-twenty-fifth of 1 per cent of such valuation in one year, shall be reimbursed once in 60 days for all further expenditure.

Limits to required expenditure by cities and towns.—No city or town with an assessed real and personal valuation of *more* than \$6,000,000 shall be required to expend in the suppression of the moths during any one full year more than one-fifteenth of 1 per cent of such valuation. No town with an assessed real and personal valuation of *less* than \$6,000,000 shall be required to thus expend during any one full year more than one-twenty-fifth of 1 per cent of such valuation.

Valuations of 1904 taken as basis.—Wherever valuations of real and personal property are referred to in the law for the suppression of the gipsy and brown-tail moth the valuations of 1904 are meant.

Wilful resistance or obstruction.—Wilful resistance to or obstruction of any agent of the Commonwealth or of any city or town, while lawfully engaged in the execution of the purposes of the moth-suppression law, is forbidden under penalty.

A. C. A. Penman
Issued January 18, 1907.

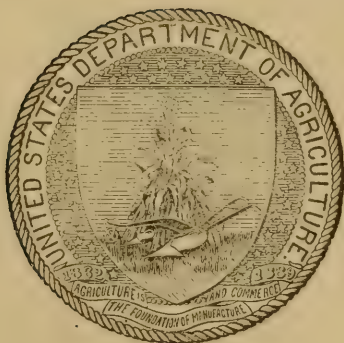
U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN 275.

THE GIPSY MOTH AND HOW TO CONTROL IT.

BY

L. O. HOWARD,
ENTOMOLOGIST.



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GOVERNMENT PRINTING OFFICE.

1907.

LETTER OF TRANSMITTAL

UNITED STATES DEPARTMENT OF AGRICULTURE.

BUREAU OF ENTOMOLOGY,

Washington, D. C., December 14, 1906.

SIR: I have the honor to transmit a brief account of the gipsy moth (*Porthetria dispar*), with some consideration of methods of control, which I believe is suited for publication as a Farmers' Bulletin.

Respectfully,

L. O. HOWARD,

Entomologist and Chief of Bureau.

Hon. JAMES WILSON,

Secretary of Agriculture.

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THE GIPSY MOTH AND HOW TO CONTROL IT.

INTRODUCTION.

The gipsy moth (*Porthetria dispar* L.) is an European insect which was accidentally introduced into Massachusetts nearly forty years ago and has since spread rather slowly, being still confined to the eastern part of Massachusetts, to Rhode Island, to the southern part of New Hampshire, and to more or less isolated localities in eastern Connecticut and southwestern Maine.

After the discovery of its presence, in 1889, the State of Massachusetts for a number of years kept up a vigorous effort to exterminate the insect, and this effort was supported by large appropriations, but was abandoned in 1900. In 1905 appropriations were again made for the purpose of attempting to suppress this insect and the brown-tail moth,^a and these appropriations are still in operation.

Although appealed to on several occasions, the National Government took no steps to assist the State of Massachusetts in its fight against this destructive species—with the exception of a small appropriation made in 1905 for the purpose of introducing its natural enemies—until the present year. At the first session of the Fifty-ninth Congress, however, the sum of \$82,500 was appropriated, to be expended by the Secretary of Agriculture, through the Bureau of Entomology, in an effort to prevent the further spread of the gipsy moth and the brown-tail moth. Under this appropriation active work is now going on in parts of New England, and the character of this work is explained in a later section of this bulletin. A popular consideration of the brown-tail moth has been published in Farmers' Bulletin No. 264, and the present bulletin is planned for the purpose of presenting in concise form what is known at the present time about the gipsy moth.

THE GIPSY MOTH IN EUROPE.

The gipsy moth has a wide distribution throughout middle and southern Europe, western Asia, and northern Africa, reaching from Stockholm on the north to Algiers on the south, and to England on the west. It extends across to eastern Asia, including Japan, and

^aSee Farmers' Bulletin No. 264, U. S. Dept. Agric., 1906.

has been found in Ceylon. In a large portion of its European range the gipsy moth is occasionally abundant and injurious; but these injurious outbreaks occur only at intervals, and in many portions of its range it becomes noticeable only very rarely. For the most part, it is satisfactorily held in check by its natural enemies.

INTRODUCTION INTO AMERICA AND SUBSEQUENT SPREAD.

Unlike the brown-tail moth, the precise time and method of introduction of the gipsy moth is well known. Prof. Leopold Trouvelot, in 1869, was connected with the astronomical observatory at Harvard University, and, for his pleasure and interest, was engaged at odd times in the study of wild silkworms, with the idea that species of commercial value might be found, and that perhaps something might be done in the way of cross breeding to produce a hardier insect than the silkworm of commerce, and one which, perhaps, might prove to be resistant to the pebrine disease which at that time was playing havoc in the silkworm establishments of Europe. He imported different silk-spinning caterpillars in different stages of existence, and among others egg clusters of the gipsy moth. He lived at 27 Myrtle street, Medford, and raised caterpillars on a shrub in his dooryard, inclosing them with a net. During a gale the net was torn and the insects scattered. He searched for them, and destroyed those found; he also gave notice of the probable escape of the species, but the affair was soon forgotten. For many years the insect was not noticed by the people of Medford, and it probably increased very slowly. It is supposed that it was gradually accommodating itself to the climate, and it is known that the neighborhood abounded with insectivorous birds and that adjoining wood lots were frequently burned over. Eventually the insect became noticeable, and by the summer of 1889 had multiplied to such an extent as to become a notorious pest; then for the first time specimens were sent to the State agricultural experiment station at Amherst and determined by Dr. H. T. Fernald as the well-known gipsy moth of Europe.

The town of Medford raised a sum of money to fight the insect, and in the spring of 1890 the State appropriated \$25,000, an additional \$25,000 being appropriated early in June. Other appropriations followed from year to year with gradually increasing amounts, and admirable work was done under the Massachusetts State board of agriculture by Mr. E. H. Forbush in charge of the field operations, and Prof. C. H. Fernald in charge of the scientific and technical work. The last appropriation was expended in 1899, and the legislature refused to vote further sums for 1900 and the following years. In 1905 the appropriations were renewed, and the work has since been carried on under a well-founded State law, the provisions of which are summarized in the concluding section of this bulletin.

The accompanying map (fig. 1) indicates accurately the infested district of Massachusetts at the time of the interruption of the State work in 1900. It also shows the district found infested in 1906, when the work of suppression was recommenced by the State. The interruption of the work is thus seen to have been almost disastrous. In

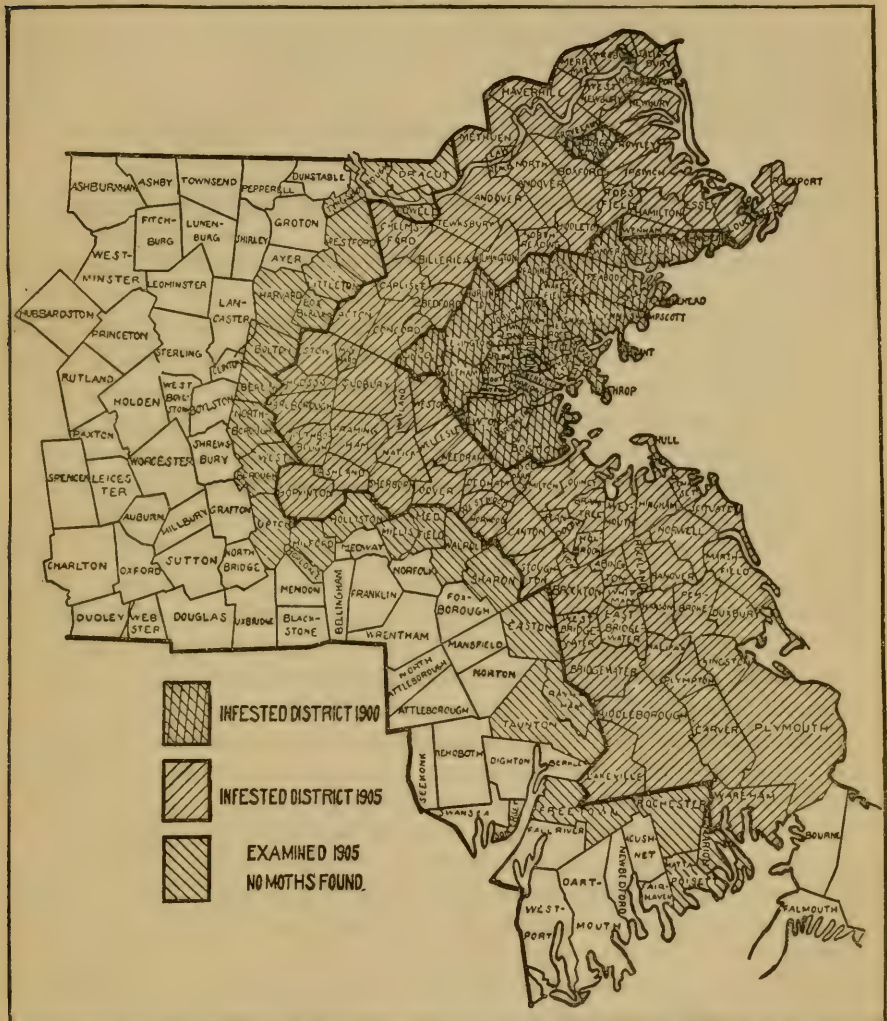


FIG. 1.—Districts in Massachusetts infested by the gipsy moth in 1900 and 1905. Infested area in 1900, 359 square miles; in 1905, 2,224 square miles. (From Kirkland.)

1899 the State board of agriculture had the problem well in hand, and at that time it seemed very probable to skilled practical entomologists who looked into the matter that even extermination was possible in the course of a comparatively short time. But the five years' interruption of the work caused the spread of the insect from a restricted

territory of 359 square miles throughout an extended range of 2,224 square miles. Beyond the limit indicated as that of 1905 the moth has probably not spread to any very great extent within the limits of the State of Massachusetts. Scouting work, however, during the early spring of 1906 and the autumn of the same year has indicated a general spread over the New Hampshire border into the southern tier of counties of that State, and recent scouting in Maine has shown the establishment of the gipsy moth at several points in the southwestern portion of that State. Moreover, it has been found near Stonington, Conn., and over a considerable space within and about the city of Providence, R. I.

THE TERRITORY NOW INFESTED IN THE UNITED STATES.

The territory at present infested may be briefly considered by States as follows:

Massachusetts.—The gipsy moth has been found in Massachusetts by the local State force in 138 cities and towns, which represent an area of about 2,480 square miles. The most seriously infested section is a group of about twenty towns just north of Boston, including a territory surrounded by Salem, Peabody, Lynnfield, Wakefield, Stoneham, Woburn, Lexington, Waltham, Watertown, and Cambridge. Within this territory almost every tree is more or less infested. Thousands of fruit trees and shade trees have been killed by this pest; in the woodlands one can easily find blocks of from 1 to 50 acres in which almost every tree is dead. During the past summer several thousand acres of these woodlands were entirely denuded of foliage. The voracious feeding of the gipsy-moth caterpillars year after year must soon cause the loss of other large areas of woodland.

Outside the badly infested area mentioned above the gipsy moth occurs in less alarming numbers, until in some of the outside towns it is only discovered after a most careful search.

The territory to the south of Boston, except the city of Quincy, is not known to be infested to a serious extent, although the moth has been discovered south to Buzzards Bay and east to Orleans. In most of the towns in this southern district there are from three or four to one hundred or more colonies. While no serious damage has yet resulted from the presence of the moth in this section of the State, the infestations are there, and unless strenuous measures are resorted to this territory will in a few years be devastated as severely as has been the country to the north of Boston.

The country to the west and north of the badly infested central region, while quite seriously infested in spots, shows the moth in decreasing numbers as we diverge from this center. The infestation extends as far west as Westboro and Ayer and north all along the New Hampshire border.

Under the State laws of Massachusetts and through its liberal appropriations, the trees on the streets and in the residential sections of the cities and towns have received sufficient attention to prevent any serious damage this year.

New Hampshire.—In New Hampshire the presence of the gipsy moth in small numbers was known in the autumn of 1905 in all of the seacoast towns and in the city of Portsmouth, but little systematic work was done until August of this year, since which time employees of the Bureau of Entomology have discovered the moth widely scattered in eight towns, which are all that have been thoroughly scouted. This territory includes Greenland, Portsmouth, Seabrook, Hampton Falls, North Hampton, and Rye. Effective scouting, however, can be done only after the leaves fall, and that now going on will probably reveal the presence of the insect over a much larger area.

Maine.—During the early autumn the gipsy moth was reported in Kittery, Me., since which time a careful scout has been made of Kittery, Eliot, and York, in all of which towns the insect has been discovered, with the probability that it will be found in other towns. Systematic scouting work is being continued in this State.

Rhode Island.—The gipsy moth was discovered in Providence, R. I., in 1901, and during that summer the city made some effort toward its eradication. From 1901 to 1906 very little work was done, and during that period the moth has spread until it now abounds in nearly every portion of the city, occurring in the largest numbers in the northeastern and southwestern sections. It has spread also into the adjoining towns of Cranston and Johnston.

There are several small but very bad colonies in Providence, some of which show infestation almost equal to the badly infested places in Massachusetts. Most of the known infestation is confined to city property, and, unless large colonies of the moth are discovered in the woodlands, a continued, aggressive campaign should result in the extermination of the pest in this territory.

Connecticut.—In the summer of 1905 the gipsy moth was discovered in Stonington, Conn., and, so far as known, it is confined to an area of about 1 square mile to the north and east of Stonington Village. During the winter of 1905 and 1906 some 60 or 70 egg clusters were destroyed; during the past summer trees were burlaped, several acres of brush land cut over, some of the stone walls burned out, and the moth vigorously hunted by the State authorities under direction of Doctor Britton. Since the egg-laying season of the past summer about 40 more egg clusters were destroyed. Unless an examination of the surrounding territory should reveal the moth over a much larger area, this colony should be entirely stamped out within a year or two, although it will require careful watching for several seasons to be sure that it does not reestablish itself.

DESCRIPTION OF THE INSECT.

The eggs.—The eggs of the gipsy moth are laid in masses (fig. 2) of about five hundred. The individual egg is minute, about the size of a pinhead, and is salmon-colored when first laid, but turns dark in the



FIG. 2.—Egg mass of the gipsy moth (*Porthetria dispar*). (From Kirkland.)

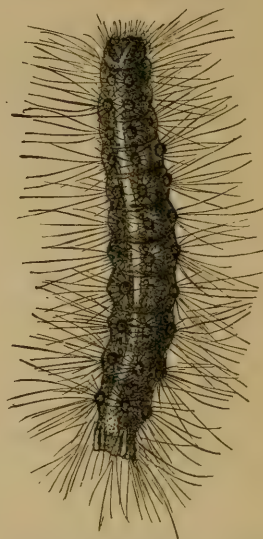


FIG. 3.—Full-grown caterpillar of the gipsy moth. Natural size (from Insect Life).

course of a few weeks. Each egg mass is yellowish in appearance and seems covered with hair. It is somewhat oval, being one-half of an inch long and about three-fourths of an inch wide. During winter,



FIG. 4.—Pupa of gipsy moth. Natural size (from Insect Life).

from exposure to moisture in the atmosphere, it becomes dingy white in color.

The larva or caterpillar.—The young larvæ or young caterpillars are dark in color and well furnished with dark hairs. The full-grown

larva (fig. 3) is between 2 and 3 inches long, dark brown or sooty in color, with two rows of red spots and two rows of blue spots along the back, and with a yellowish but rather dim stripe between them. The body generally is clothed with long hairs, and sometimes reaches the length of 3 inches.

The pupa.—The pupa (fig. 4) is not inclosed within a perfect cocoon, but the full-grown larva spins a few threads of silk as a sort of support and changes to the pupa, which is dark reddish or chocolate in color and very thinly sprinkled with light reddish hairs.



FIG. 5.—Male gipsy moth. Slightly enlarged (from *Insect Life*).

The adult or moth.—The male moth (fig. 5) is brownish yellow in color, sometimes having a greenish-brown tinge; it has a slender body, well-feathered antennæ, and a wing expanse of about an inch and a half. The forewings are marked with wavy zigzag darker lines. It flies actively all day as well as by night.



FIG. 6.—Female gipsy moth. Slightly enlarged (from *Insect Life*).

The female moth (fig. 6) is nearly white, with slender black antennæ, each of the forewings marked with three or four zigzag, transverse, dark lines, and the outer border of both pairs of wings with a series of black dots. The body of the female is so heavy as to prevent flight.

SEASONAL HISTORY.

The moths emerge from the pupæ from the middle of July to the middle of August, the date varying considerably according to the season. After mating they live but a short time, and the female dies after depositing her eggs.

The eggs are laid therefore in July and August. They are deposited by the moths on the trunks of the trees upon which the caterpillars have lived, and in fact usually in the vicinity of the place where the

female has transformed. The caterpillars before transforming frequently crawl for some distance from the trees upon which they have been feeding, and it therefore happens that the egg masses will be found on fences and in all sorts of protected situations in which the caterpillars hide during the day. The crevices in stone fences often contain very many of these egg masses, and knot holes in old trees will also contain many which would not at first be discovered. The egg masses are found also in hollow trees, in crevices under rough bark, on shrubbery, on buildings, in wood piles, in barrels, in boxes, and among rubbish in dooryards. The moths seem to choose the inner or lower surface of an object upon which to lay their eggs, and therefore egg masses are placed out of sight perhaps as often as in sight.

The eggs hatch about May 1, and the young caterpillars begin immediately to feed, usually upon the lower surfaces of the leaves. As they grow they cast their skins several times, and as they become larger they feed only at night, hiding during the daytime, usually in clusters on the shady side of tree trunks, beneath large limbs, in holes in trees, under loose bark, and in fact under any nearby shelter. It is the habit of most of them to descend before daybreak upon the trunks of the trees and to seek for such shelters as those just indicated, returning after nightfall to resume their nocturnal feeding.

The larvæ usually become full grown about the 1st of July, and then transform to pupæ. The pupæ are found in the same situations as those we described for the egg clusters, but are found also in the foliage of trees and shrubs.

HOW THE INSECT SPREADS.

As indicated above, the bodies of the females are so heavy as to prevent flight. Therefore the insect must be principally distributed while in the caterpillar or larval condition. The caterpillars are active crawlers, but as a rule do not migrate from the localities where they were born except when food is scarce. When young, and when there is hardly enough food, the larvæ spin down from trees by means of silken threads and often alight upon vehicles of one kind or another, and are thus carried often for great distances from the place of birth. Trolley cars, carriages, automobiles, and bicycles are thus means of transportation almost unlimited in their possibilities. The caterpillars often crawl upon vehicles which happen to stand for any length of time in an infested locality, and thus may be carried great distances. Sometimes even pedestrians aid unwittingly in this distribution, since the caterpillars may drop by their threads upon the garments of a person passing under an infested tree.

The species may be transported, too, in the egg stage. It has been shown that the egg clusters are laid upon many different kinds of objects. Cord wood stacked and piled may be carried away in the autumn bearing many egg masses, and, if not burned before summer, larvæ may issue in a new locality. The same may be said for lumber piles near infested trees. Freight cars may have been sidetracked near an infested place long enough to permit laying of the eggs upon them.

It is by these methods that the comparatively rapid spread of the insect previously noticed, during the years 1900-1905, is to be explained.

DAMAGE TO PLANTS.

The larva of the gipsy moth feeds upon the foliage of practically all orchard trees, all shade and ornamental trees, all out-of-door shrubs, and all forest trees. Not only are the deciduous forest trees stripped, but the coniferous trees as well. In June and July patches of forests in the infested territory are stripped of every green leaf and the trees appear as bare as in winter. After several such consecutive strip-pings, deciduous forest and shade trees are killed, but with a coniferous tree, such as a pine, hemlock, or spruce, one complete stripping will cause death. It is this fact which makes the gipsy moth so much more serious a pest than the brown-tail moth, and the loss which will result from its spread into northern New England will be very great, owing to the enormous coniferous forest interests in that part of the country.

In cities and towns the insect does damage not only by destroying all vegetation, but by swarming in numbers upon and about houses, frequently entering them. It has been the experience in eastern Massachusetts that where a locality becomes thoroughly infested the value of real estate rapidly depreciates, and it becomes a matter of difficulty to rent or sell property.

Among its food plants the gipsy moth caterpillar seems to prefer apple, white oak, red oak, willow, and elm, but those who have studied it most carefully in Massachusetts say that it will on occasion devour almost every useful grass, plant, flower, shrub, vine, bush, garden, or field crop that grows in the State.

NATURAL ENEMIES AND PARASITES.

Observations extending over a number of years show that birds have some importance as enemies of the gipsy moth. As already suggested, the fact that the insects spread comparatively slowly in the vicinity of Medford between the years 1869 and 1889 is probably to be accounted for in part by the fact that insectivorous birds were much more numerous in that part of Massachusetts during that period than they have

been since. Not only have the English sparrows (which, by the way, feed but rarely upon the gipsy moth) driven away many of the other birds, but pot-hunters from Boston and from the manufacturing towns about Boston, especially persons of foreign birth, have destroyed great numbers of insectivorous birds. The caterpillars are preyed upon by the cuckoos, the Baltimore oriole, the yellow-throated vireo, and the blue jay. The moths, when they emerge, are eaten by many birds, and the eggs are eaten by several species.

Certain of our native parasites which destroy allied insects like the fall webworm and the tussock moth also breed in the gipsy moth caterpillar and chrysalis. A number of species were bred during the early Massachusetts State work, but the percentage of parasitism was very small.

An effort is being made by the Bureau of Entomology, in cooperation with the Massachusetts State authorities, to introduce the European parasites of the gipsy moth, and of the brown-tail moth as well, and during the past year many thousands of such parasites have been introduced and liberated in the vicinity of Boston. They are first cared for in a laboratory at North Saugus; many of them are afterwards studied under out-of-door tents, while still others have been liberated in the open and badly infested woodlands, such locations for liberation having been chosen as are likely to remain undisturbed either by insecticidal operations or by forest fires. The results so far are encouraging, but it may be, and probably will be, several years before appreciable results will be obtained, and it may be that these European parasites will not increase as rapidly or do as good work as they are known to do in Europe. In the Old World, as has been previously indicated, the gipsy moth is only occasionally present in sufficient numbers to do noteworthy damage, and it is ordinarily kept in check by its parasites and other natural enemies. In this country, therefore, active mechanical measures must still be continued, and perhaps for years to come, in the actual destruction of the injurious insect before relief from parasites is gained.

REMEDIES.

The gipsy moth, when occurring in moderate numbers, is not at all a difficult insect to fight. When young the caterpillars are readily killed by spraying the trees with the ordinary arsenical poisons. As they grow older they develop a remarkable resistance to the action of arsenic, so that stronger and stronger proportions must be used. It was early found that Paris green and London purple can not be used effectively against well-grown larvæ unless the proportion of the arsenical to the amount of water is so great as to burn the foliage of the trees or

plants. Therefore the substance known as arsenate of lead, which admits of much stronger proportions without damage to foliage, was introduced and has since been extensively used, not only against the well-grown gipsy moth larvæ, but against other leaf-eating insects.

But against the larger larvæ other measures may be used to advantage. It has been pointed out that it is the habit of the larvæ to descend upon the trunk of the tree in the early morning and to hide under any protection until nightfall. Therefore, if a strip of burlap or other coarse, cheap cloth is tied about an infested tree trunk by the middle, in such a manner that the flaps hang down (see fig. 7), the caterpillars, as soon as they have reached this stage, will gather for the day under the cloth and can be destroyed by crushing or cutting. The burlap should be examined daily, and may be employed from the latter half of May to the first or middle of August—as late as the latter date, for the reason that many caterpillars transform to pupæ under the burlap and many egg masses are also laid under it. As Kirkland has well expressed it, “It should be borne in mind that the cloth band is in no sense a tree protector; nor is it a trap. Its function is simply to give the shelter which the caterpillars seek by day. Serving as it does as a hiding place for various insects, it is better off the tree than on unless it can be attended to and kept clean. At the end of the caterpillar season all burlaps should be removed and burned. To insure best results on high trees, such as street elms, burlaps should be placed around some of the larger limbs, as well as around the trunk, as many caterpillars will seek shelter up in the tree rather than descend to the ground. The most effective results in using the burlap are obtained where cavities, crevices, etc., in the trees have been first filled with cement or covered with zinc and all loose bark removed. If these hiding places are destroyed nearly all the caterpillars will seek the burlap at some time during the season.”

One of the most effective methods of destruction consists in killing the eggs. The egg masses are often conspicuous and accessible and may be destroyed by applying creosote mixtures by a small swab or paint brush. This mixture may be bought at agricultural warehouses and seed stores at from 50 cents to \$1 a gallon. Every egg mass thus treated means the destruction of 500 potential caterpillars. The egg clusters should be creosoted early in the autumn if possible, since they are likely to be broken and the eggs scattered on the ground by the rubbing of animals against the trees, or by the breaking open of the

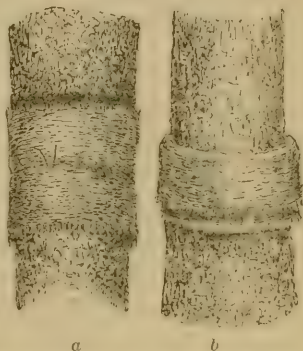


FIG. 7.—Manner of applying burlap bands: *a*, band as originally tied; *b*, band with upper half turned down. Greatly reduced (after Forbush).

clusters by cats and squirrels, or by the picking of birds, thus also scattering the eggs. Much good can also be accomplished by burning over unimproved tracts of brush land and burning out the undergrowth in sparse woodlands. Where the clusters are very plentiful, burning the ground over with oil to destroy eggs scattered as the result of the cutting of trees and bushes will, according to Kirkland, be required to insure thorough work. The burning method is also effective in May or June, after the young larvæ have hatched.

With the creosoting of the eggs, the spraying against the young larvæ, the burlaping against the old larvæ, and with burning in places indicated, the insect may be kept in check. So great, however, is the prolificacy of the species, and in such enormous numbers does it occur in eastern Massachusetts, that the thorough use of these and other methods of destruction upon a large estate involves a great expenditure of money. For example, Gen. S. C. Lawrence for a number of years kept a large force of men working upon certain gipsy moth colonies in his own and adjoining forest lands, and expended each year more than the actual value of the lands. This experience, however, need not and should not discourage small property holders from vigorous efforts to destroy the insects upon their own holdings. Unless extraordinarily abundant, it is perfectly feasible to hold them in check.

One of the most serious features of the damage is the injury in park lands in eastern Massachusetts, where thousands of acres are infested and where important problems exist. From long experience the best methods for treating these wooded sections have been proven to be the cutting out and burning of all underbrush, the removal of trees which have died or have inaccessible cavities in them, and the burning of all refuse on the ground. It is almost impossible to inspect the thick growths of underbrush for the various stages of the moth, and there is no method for their treatment at a reasonable cost. Trees which have been scarred by forest fires, or from other causes, often have cavities in them which provide admirable hiding places for these insects, and should be removed to prevent the constant expense of inspection.

Apple orchards, also, aside from those receiving the most careful attention, offer favorable breeding places for the moth. There are in New England thousands of old, badly infested apple trees which have passed their usefulness for producing good fruit, and the ground which they occupy might better be devoted to other crops or to newly set orchards. The field force rarely goes into an orchard that has not several trees with holes in them which might harbor the gipsy moth so safely that its presence could not be detected unless the tree were cut open. Such trees, if not worth being cared for by cementing or tinning the holes to prevent the entrance and exit of the gipsy moth, should be cut and burned.

Hedges of brush along roadsides and stone walls also offer favorable breeding and hiding places for the pest. In such places the presence of the moth may not be discovered for several years, the caterpillars feeding upon the brush and nesting in stone walls until the colony has developed to sufficient size to attract attention by its depredations on neighboring trees, upon which its presence is easily discovered. The cutting and burning of these rows of worthless shrubbery each year until killed not only removes a favorite hiding place for various insect pests, but also gives the roadside and farm a much more trim appearance.

WHAT THE STATE OF MASSACHUSETTS IS DOING FOR THE CONTROL OF THE INSECT.

In the session of the Massachusetts legislature in the spring of 1905 a law was passed which had for its object the suppression of the gipsy and brown tail moths. The essential features of this law are as follows:

FEATURES OF THE MASSACHUSETTS LAW.

The moths are public nuisances.—The gipsy and brown tail moths are declared public nuisances and their suppression is required.

The superintendent of suppression.—A superintendent appointed by the governor with power, subject to the governor's approval, of appointing agents and assistants has entire general charge of the work of suppressing the moths.

Duties of cities, towns, and individuals.—Cities and towns (under the advice and general direction of the superintendent, and by such agent as they may designate or appoint) are required, under penalty for neglect, to destroy the eggs, pupæ, and nests of the gipsy and the brown-tail moths within their limits, *excepting* that such work is not to be done by cities and towns on property controlled by the Commonwealth, nor is it to be done upon private property, excepting where the owners of the same fail to destroy the eggs, pupæ, and nests of the moths, in accordance with the terms of the official notice to private owners noted in the section here following:

Notice to private owners.—The mayor of every city and the selectmen of every town shall, at suitable times, notify every owner of land located therein which is infested with the moths, requiring him to destroy the eggs, pupæ, and nests of the moths within a specified time.

When the mayor or selectmen decide that the cost of such destruction (on lands contiguous and under one ownership) will exceed one-half of 1 per cent of the assessed valuation of the lands, then they may designate in the notice a part only of such lands on which the destruction shall take place.

Failure of private owners to destroy moths.—If the owner does not, as required by the terms of the aforesaid notice, destroy the eggs, pupæ, and nests of the moths, then the city or town, subject to the approval of the State superintendent, shall destroy them, and shall assess upon such aforesaid lands the actual cost of so doing, to an amount, however, not exceeding one-half of 1 per cent of the assessed valuation of the land.

This amount, so assessed, shall be collected in the form of taxes, and constitutes a lien upon such lands.

Redress by abatement and appeal.—The assessors may abate the moth assessment in the case of any private landowner decided by them to be unable to pay it because of age, infirmity, or poverty.

Appeal to the county superior court, with special provision for prompt hearing, is provided by the statute for any person aggrieved by assessment on account of this work; provided a complaint is entered within 30 days of notice of such assessment.

Appropriation by the Commonwealth.—To meet the expenses incurred under its moth-suppression law the Commonwealth has appropriated \$300,000. Of this sum \$75,000 may be expended during 1905, \$150,000 (and any unexpended balance) during 1906, and \$75,000 (and any unexpended balance) during 1907, up to May 1, 1907, inclusive.

For the purpose of experimenting with natural enemies for destroying the moths, \$10,000 is additionally appropriated for each of the years 1905, 1906, and 1907.

Reimbursements to cities and towns.—(1) Cities and towns with valuation of real and personal estate of \$12,500,000 or more, having spent \$5,000 in any one calendar year, shall be reimbursed annually 50 per cent (one-half) of all further expenditure in combating this pest.

(2) Cities and towns with valuation less than \$12,500,000 and more than \$6,000,000, having spent an amount equal to one twenty-fifth of 1 per cent of such valuation in one year, shall be reimbursed annually 80 per cent (four-fifths) of all further expenditure.

(3) Towns with valuation less than \$6,000,000, having spent an amount equal to one twenty-fifth of 1 per cent of such valuation in one year, shall be reimbursed once in 60 days for all further expenditure.

Limits to required expenditure by cities and towns.—No city or town with an assessed real and personal valuation of more than \$6,000,000 shall be required to expend in the suppression of the moths during any one full year more than one-fifteenth of 1 per cent of such valuation. No town with an assessed real and personal valuation of less than \$6,000,000 shall be required to thus expend during any one full year more than one twenty-fifth of 1 per cent of such valuation.

Valuations of 1904 taken as basis.—Wherever valuations of real and personal property are referred to in the law for the suppression of the gipsy and brown-tail moth the valuations of 1904 are meant.

Willful resistance or obstruction.—Willful resistance to or obstruction of any agent of the Commonwealth or of any city or town, while lawfully engaged in the execution of the purposes of the moth-suppression law, is forbidden under penalty.

Under this law, Mr. A. H. Kirkland, a very well equipped man, was appointed superintendent, organized an effective force, and during the seasons of 1905 and 1906 has done excellent work. The experiences of these two years have shown certain defects in the law, which it is hoped will be remedied at the coming session of the State legislature.

WHAT OTHER STATES HOPE TO DO.

The comparatively recent spread of the gipsy moth into the States of New Hampshire, Connecticut, Rhode Island, and Maine, as indicated in an earlier paragraph of this bulletin, has created great public interest in these States, and at the coming sessions of the legislatures efforts will be made in each State to secure the passage of a law based upon the Massachusetts State law summarized above. In the meantime the State of Rhode Island has expended a certain amount of money appropriated by the legislature last winter, and the State of Connecticut has used certain funds at the disposal of the Director of the State agricultural experiment station. In New Hampshire and Maine no State work has yet been done.

WHAT THE NATIONAL GOVERNMENT IS DOING.

Congress at its last session appropriated, as elsewhere stated, the sum of \$82,500 to be expended in an effort to prevent the further spread of the gipsy moth and the brown-tail moth. This money became available July 1, 1906, so that it was impossible to perfect the organization of the work in time to attempt any extended measures against the caterpillars this season. Mr. D. M. Rogers, formerly Mr. Kirkland's first assistant, was appointed special agent of the Bureau of Entomology in charge of the field work, a force of inspectors and laborers was organized, and work was begun about the middle of July.

After looking over the whole field and discussing the question at length with Messrs. Kirkland and Rogers, the writer concluded that since it seems obvious that nearly all of the recent spread of the gipsy moth has taken place by means of vehicles coming from the interior of the most thickly infested regions, the most effective manner of preventing further extensive spread would be to clean up the main traveled roads in the most thickly infested portions of the old gipsy-moth

territory. The main work, therefore, was begun in the State of Massachusetts, and forces of men were placed on the principal infested roads to clean the shade trees and the underbrush for some distance back from the roads, in order that there may be no opportunity the coming season for caterpillars to spin down upon vehicles or passers-by, and thus to be carried to distances.

By cooperation with the State authorities in Rhode Island and Connecticut an effort has been made to stamp out the isolated colonies in these two States. This work has been actively carried on throughout the year, the Bureau paying for the services of the laborers and controlling their work in Rhode Island, but in the Connecticut case leaving affairs in charge of the State authorities.

Scouting parties have been and are working in New Hampshire and Maine in the effort accurately to map every infested point in order that all isolated colonies may be destroyed.

All of this work will be continued until the close of the fiscal year, and afterward provided Congress shall renew the appropriation.

The Government field office for gipsy-moth work is at No. 6 Beacon street, Boston, Mass., and the special field agent in charge is Mr. D. M. Rogers.

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The following is a list of the Farmers' Bulletins available for distribution, showing the number, title, and size in pages of each. Copies will be sent free to any address in the United States on application to a Senator, Representative, or Delegate in Congress, or to the Secretary of Agriculture, Washington, D. C. Numbers omitted have been discontinued, being superseded by later bulletins.

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Issued April 29, 1907.

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 283.

SPRAYING FOR APPLE DISEASES AND THE CODLING MOTH IN THE OZARKS.

BY

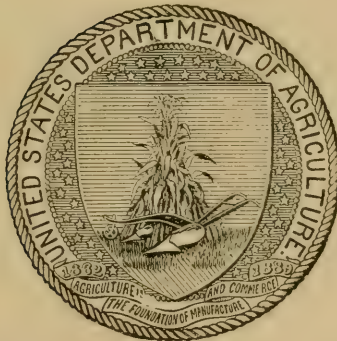
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OF THE BUREAU OF PLANT INDUSTRY,

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
Washington, D. C., January 26, 1907.

SIR: We have the honor to transmit herewith the manuscript of a bulletin entitled "Srraying for Apple Diseases and the Codling Moth in the Ozarks," by W. M. Scott, of the Bureau of Plant Industry, and A. L. Quaintance, of the Bureau of Entomology. We recommend that this be published as a Farmers' Bulletin. The work was conducted under the joint direction of our two Bureaus and has resulted in a remarkably successful demonstration of methods of controlling a number of the most serious fungous and insect pests affecting the orchards of this important fruit region.

The accompanying illustrations are necessary to a clear understanding of the text.

Respectfully,

B. T. GALLOWAY
Chief, Bureau of Plant Industry
L. O. HOWARD,
Chief, Bureau of Entomology.

HON. JAMES WILSON,
Secretary of Agriculture.

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SPRAYING FOR APPLE DISEASES AND THE CODLING MOTH IN THE OZARKS.

INTRODUCTION.

During the past fifteen or twenty years the Department of Agriculture and many of the State agricultural experiment stations have been devoting much time to the study of apple diseases and insects and to conducting practical experiments in their control. Much information on this subject has been accumulated and made available for the use of orchardists through publications and correspondence, and the apple-growing industry of the country has been enormously benefited thereby. The increasing losses due to insects and diseases, following their more general dissemination and an increased food supply, has rendered their control imperative in the successful growing of this fruit, and perhaps no other crop derives such a large percentage of benefit from the use of remedial and preventive measures.

Although there are many apple growers who are successfully controlling the diseases and insect pests of their crop, perhaps the majority have not availed themselves of the remedies at hand, or are not securing satisfactory results, largely owing to lack of sufficient attention to details or to imperfect use of remedies. While some benefits have followed careless spraying, the results in many cases have not appeared to warrant the necessary outlay in expense and labor, resulting in discouragement to the grower and apparent discredit to the recommendations. Indeed, some fruit growers have come to believe that the recommended measures are entirely without merit.

The treatment for the important fungous and insect troubles of the apple mostly takes the form of spraying, and, as will at once appear, great variation is possible in the comparative thoroughness with which applications may be made. Good results also depend upon the proper preparation of sprays, the efficiency of the pumps, and the time applications are made. It is seen, therefore, that several factors are involved, the neglect of any one of which may result in partial or total failure. It has therefore appeared desirable to carry the work beyond experimentation and actually demonstrate on a commercial

scale to orchardists the proper use and efficiency of control measures that have been evolved from careful experiments.

Accordingly, work of this character was planned by the Bureau of Plant Industry and the Bureau of Entomology for the season of 1906 and was carried out in apple orchards in the Ozark regions of Arkansas and Missouri, in the latter State in cooperation with the Missouri State Fruit Experiment Station. Similar work was also carried out in several counties in southeastern Nebraska, in cooperation with the Nebraska Agricultural Experiment Station. In the work herein reported the writers have had the assistance of Messrs. J. B. Rorer, F. W. Faurot, and Dudley Moulton.

SCOPE OF THE WORK.

The predominating troubles in the apple orchards of the Ozark region are apple scab, bitter-rot, apple blotch, leaf-spot, and, among insects, the codling moth. A plan of treatment was formulated which should as nearly as possible give protection from all these affections, namely, the application of Bordeaux mixture and an arsenical at such times as a knowledge of the affections indicated that spraying was necessary.

This work in Arkansas was conducted in Bentonville and vicinity, in the orchards of Mr. H. W. Gipple, Capt. George T. Lincoln, and Doctor Alden. In the Gipple orchard 200 Ben Davis and 100 Winesap trees were sprayed. In the Lincoln orchard 250 trees, about equally divided among the Jonathan, Ben Davis, Gano, and Givens varieties, and in the Alden orchard 200 Ben Davis trees were treated.

In Missouri the orchard of Fassnacht Brothers, at Springfield, and that of Mr. J. E. Hansell, at Fordland, were selected. In the Springfield orchard, 75 Huntsman and 200 Ben Davis trees were used, and in the Fordland orchard 400 Jonathan, 100 Gano, and a few Ben Davis trees were treated.

ORCHARD CONDITIONS IN THE OZARKS.

The growing of apples in the Ozarks has within comparatively recent years become a very important industry, and in that region are to be found some of the largest apple orchards of the country, in some instances covering from 500 to 1,000 acres. As a rule, however, the orchards are much smaller, ranging from 40 to 100 acres. The principal commercial varieties grown are Ben Davis, Gano, Jonathan, and Winesap, the Ben Davis and Gano varieties predominating. Trees are generally planted about 30 feet apart and come into bearing early, usually in from six to eight years. Growth is fairly vigorous, but trees do not as a rule reach large size, in part due to their early bearing. Many orchards have not had adequate cultivation, but have

been permitted to grow up in shrubs, weeds, and briars. The effect of this neglect was generally apparent during 1906, the crops in neglected orchards being very light or there being no crop, whereas in well-cared-for orchards the yield has invariably been good.

As a rule, sufficient attention has not been given to the control of diseases and insects, and under such conditions these have become quite abundant and destructive. While numerous orchardists have supplied themselves with spraying outfits and have sprayed their trees, many very soon abandoned the practice, not having secured satisfactory results. The principal difficulty appears to have been lack of information concerning the troubles to be controlled and failure to comprehend what constitutes thorough spraying.

PLAN OF WORK.

A plan of treatment was adopted which called for sprayings with Bordeaux mixture having an arsenical added, except in the first treatment, as follows:

First application, when cluster buds opened, but prior to blooming.

Second application, as petals fell.

Third application, seven days later.

Fourth application, thirty days after petals fell.

Fifth application, June 25.

Sixth application, July 17.

Seventh application, August 11.

Specifically these treatments were designed to control the apple scab, codling moth, leaf-spot, apple blotch, and bitter-rot, all of which affections are quite destructive in Ozark orchards.

The early treatments were for the apple scab and the first generation of the codling moth. The later treatments, beginning with June 25, were for bitter-rot, apple blotch, leaf-spot, and the second brood of codling moth.

In practice it was not found possible to make the applications entirely as planned, but the scheme was approximately carried out, as will be detailed in the consideration of the respective affections.

BITTER-ROT.^a

INJURY.

Bitter-rot is a fungous disease of the apple, which causes decay of both green and ripe fruit, rendering it unfit for market. It was reported as seriously destructive in Illinois as early as 1869, and with the increased development of the apple industry since that date it

^aFor a more extended account of this disease and successful experiments in its control, see Bul. 93 of the Bureau of Plant Industry, U. S. Dept. of Agriculture, by W. M. Scott.

has appeared at irregular intervals with increasing severity in various sections of the more southern parts of the apple belt. In recent years the losses from this malady have been specially severe, amounting during some seasons to several millions of dollars. The fact that it may suddenly attack and destroy the entire crop of an orchard as the fruit approaches maturity has brought about a general dread of the trouble, and has caused a depreciation in the value of orchards in infested regions.

DESCRIPTION.

The disease first appears on the fruit as very minute yellowish-brown spots, frequently surrounded by purplish or reddish areas. These spots, which are circular in outline, gradually enlarge, assume a dark brown color, and, owing to a shrinking of the invaded tissue,



FIG. 1.—A Yellow Newtown apple affected with bitter-rot, and a mummified fruit of the preceding year's crop. (From Scott.)

become more or less depressed. By the time the spots reach one-fourth to one-half inch in diameter, minute, black, slightly raised fruiting pustules begin to appear, arranged in more or less concentric rings. These soon break through the skin, discharging pinkish masses of spores, and as the disease advances other rings of pustules are produced. The pink spore masses are more in evidence during periods of fair weather, as they are readily washed off by rains and are even dissolved out by heavy dews, leaving visible the small black openings of the pustules.

Only a single diseased spot may appear on an apple, but frequently there are several of varying sizes, and in a serious outbreak the fruit may be literally peppered with small points of infection and numerous larger spots. In such cases a few of the spots grow rapidly and envelop the others, and, although coalescing more or less, retain their individual

outline, each producing its concentric rings of fruiting pustules. Most of the diseased fruits fall to the ground by the time or before they are half decayed, but some may become entirely rotten, dry up in a mummified condition, and hang on the tree for a year or more. This disease is illustrated in figure 1, which shows an apple affected with bitter-rot and a mummified fruit from the preceding year's crop.

THE CAUSE.

The familiar spots on the apple known as bitter-rot are caused by the growth in the tissues of the fruit of the fungus *Glomerella rufomaculans* (Berk.) Spauld. and v. Schrenk. The infection starts from very minute spores, which, falling on the surface of the apple, germinate in the presence of moisture, and the resulting tube-like growth penetrates the skin and immediately begins to branch and grow rapidly, destroying the invaded tissue and soon producing the circular, brown, sunken area already noted. The fungus penetrates toward the center of the apple about in proportion to its rate of growth as seen on the surface, and eventually the fruit, as it decays, becomes filled with the minute, almost colorless threads of the fungus.

After a time spore-bearing branches of the fungus are produced near the surface of the diseased spot, and these soon rupture the skin, giving forth pinkish masses of spores or conidia, by which the disease is principally spread. From a single diseased spot are produced many millions of spores, sufficient to furnish infection under certain conditions for an entire orchard. On the decayed apples which have fallen to the ground the perfect stage of the fungus is produced during the autumn and perhaps also the following spring. This stage serves to carry the fungus over winter and its spores are perhaps a source of infection of the new crop of apples. With the warmth and moisture of spring and early summer the fungus in mummified fruits on the trees resumes growth, producing conidia or summer spores, which serve to infect the new crop.

Canker.—The bitter-rot fungus also occurs on limbs and twigs of the apple tree, affecting the bark and cambium and producing what are known as cankers. The diseased area is sooty black, sunken, and from 1 inch to several inches in length, and the bark usually becomes cracked. Both winter and summer spores are formed in these cankers, which doubtless constitute an important source of infection of the fruit.

CLIMATIC INFLUENCES.

Bitter-rot is essentially a hot-weather disease, and its period of infection is mostly during the months of July, August, and September. Injury from it is rarely noticed before the middle of June, but with

suitable weather conditions it becomes increasingly marked as the season advances. Hot, showery weather is ideal for the development of the disease. Moisture is necessary for the germination of the spores, and a high temperature favors the growth of the fungus.

DEMONSTRATION SPRAYING FOR BITTER-ROT IN ARKANSAS.

The demonstration work was done at Bentonville, Ark., and treatment for bitter-rot was included in all the demonstration spraying at that point, but only the results obtained in the orchard of Capt. George T. Lincoln will be here discussed in detail.

This orchard was not at first selected for the general demonstration work, and it was not until July 10, after considerable infection of the fruit had taken place, that spraying was begun. On July 6 Captain Lincoln called our attention to a slight outbreak of the disease on his Jonathans, and upon investigation on July 8 from 1 to 20 affected fruits were found on each of various trees of the Jonathan, Gano, and Ben Davis varieties, and on July 10 as high as 50 diseased fruits per tree were counted on the Jonathan trees. The other variety, the Givens, appeared to be free from rot at that time. Arrangements were immediately made with Captain Lincoln for spraying a block of 250 trees about equally divided among the four varieties, and leaving 6 trees of each variety untreated as checks. Some of these check trees were left together in two rows running a third of the way through the block, near the center, while the others were distributed in other portions of the block. The trees were ten years old and in good condition, having been thoroughly pruned and well cultivated, but during the past two seasons the orchard was in clover sod.

The treatment.—The entire block, excepting the check trees, was sprayed with Bordeaux mixture on July 10, July 26, and August 9, and the Givens trees, which mature their fruit some three to four weeks later than the other varieties, received an additional application on August 27. The Bordeaux mixture was composed of 5 pounds of copper sulphate and 5 pounds of lime to 50 gallons of water, to which 2 pounds of arsenate of lead were added for protection against the codling moth. The trees were thoroughly sprayed, especial care being taken to reach every apple so far as practicable. For the first two applications a good hand pump, mounted on a 100-gallon tank and equipped with two 30-foot leads of half-inch hose and double Vermorel nozzles, was used. The other applications were made with a gasoline-power sprayer, with a 200-gallon tank, three 35-foot leads of $\frac{3}{4}$ -inch hose, and triple Vermorel nozzles, a tower being employed to reach the tops of the trees.

The results.—Although the disease was well established in the orchard before treatment was begun, the results were quite good,

exceeding expectations. The spread of the disease was immediately checked by the first spraying and held under control by the succeeding applications. The invisible infections that had taken place before the treatment was begun developed into rotten spots under the coating of Bordeaux mixture, and a few fresh infections took place just before the crop was picked, the mixture having been partly washed off. On the other hand, the disease continued to develop on the unsprayed trees, new infections taking place from time to time through the season, so that very little sound fruit was left on these trees at picking time. Rains occurred at frequent intervals, furnishing ample moisture for infection.

The apples from 6 sprayed trees and 3 unsprayed or check trees of each variety were classified into rotten and sound fruit, the term "sound" applying to all fruits not affected with bitter-rot. The windfalls were included, and the apples of each class were both counted and measured. The results are shown in Tables 1 to 4:

TABLE 1.—*Comparison of sound and bitter-rot affected fruit from sprayed and unsprayed trees of the Jonathan variety, Lincoln orchard, Bentonville, Ark., 1906. Fruit picked August 29 and 30.*

Date of spraying and tree number.	Yield.	Sound apples.	Diseased apples.	Percentage of sound fruit.
Trees sprayed July 10 and 26 and August 9:	<i>Bushels.</i>	<i>Number.</i>	<i>Number.</i>	
No. 1.....	15.76	1,278	144	89.87
No. 2.....	18.26	1,563	253	86.06
No. 3.....	18.76	1,526	163	90.34
No. 4.....	10.26	749	103	87.91
No. 5.....	13.76	1,394	17	98.79
No. 6.....	24.50	2,164	309	87.50
Nos. 1 to 6 combined.....	101.30	8,674	989	89.76
Trees not sprayed:				
A.....	5.875	3	1,276	.23
B.....	9.35	135	1,670	7.47
C.....	5.875	50	1,298	3.70
A, B, and C combined.....	21.10	188	4,244	4.24

Table 1 shows the results from 6 sprayed Jonathan trees, separately and combined, and 3 unsprayed trees of the same variety, separately and combined. It will be noted that the average percentage of sound fruit from the sprayed trees is 89.76, while that of the 3 unsprayed trees is 4.24, the crop from the latter being almost entirely lost. It will be remembered that the Jonathan trees were the first to become infected, as many as 50 diseased fruits having been found on some trees at the time of the first application, and perhaps others had invisible points of infection. This largely accounts for the 10 per cent of loss sustained on the sprayed trees. Indeed, it was not expected that such a high percentage of sound fruit could be obtained after the disease had gained such a foothold.

TABLE 2.—*Comparison of sound and bitter-rot affected fruit from sprayed and unsprayed trees of the Gano variety, Lincoln orchard, Bentonville, Ark., 1906. Fruit picked September 6.*

Date of spraying and tree number.	Yield.	Sound apples.	Diseased apples.	Percentage of sound fruit.
Trees sprayed July 10 and 23 and August 9:	<i>Bushels.</i>	<i>Number.</i>	<i>Number.</i>	
No. 1.....	22.50	1,877	6	99.68
No. 2.....	19.26	1,594	2	99.87
No. 3.....	13.26	1,081	24	97.82
No. 4.....	21.52	1,711	17	99.01
No. 5.....	12.25	1,791	4	99.77
No. 6.....	8.00	1,170	10	99.15
Nos. 1 to 6 combined.....	96.79	9,224	63	99.32
Trees not sprayed:				
A.....	17.54	841	560	60.02
B.....	21.76	520	1,123	31.64
C.....	15.52	26	1,242	2.05
A, B, and C combined.....	54.82	1,387	2,925	32.16

Bitter-rot was not so severe on the Gano as it was on the Jonathan trees, but the crop on some of the unsprayed trees of the former variety was scarcely worth picking. As seen in Table 2, 99.32 per cent of the crop from 6 Gano trees was free from the disease, while only 32.16 per cent of sound fruit was obtained from the 3 checks.

TABLE 3.—*Comparison of sound and bitter-rot affected fruit from sprayed and unsprayed trees of the Ben Davis variety, Lincoln orchard, Bentonville, Ark., 1906. Fruit picked September 17.*

Date of spraying and tree number.	Yield.	Sound apples.	Diseased apples.	Percentage of sound fruit.
Trees sprayed July 10 and 23 and August 19:	<i>Bushels.</i>	<i>Number.</i>	<i>Number.</i>	
No. 1.....	18.73	2,101	27	98.73
No. 2.....	13.58	1,793	12	99.33
No. 3.....	6.36	825	30	96.37
No. 4.....	11.34	1,524	30	98.06
No. 5.....	4.00	541	2	99.63
No. 6.....	16.51	1,906	177	91.50
Nos. 1 to 6 combined.....	70.52	8,690	278	96.90
Trees not sprayed:				
A.....	2.60	18	801	2.19
B.....	9.64	92	1,456	5.94
C.....	11.88	169	1,416	10.66
A, B, and C combined.....	24.12	279	3,673	7.05

In Table 3 the results from the treatment of the Ben Davis trees are given, the 6 sprayed trees yielding an average of 96.9 per cent of sound fruit and the 3 check trees only 7.05 per cent. Practically the entire crop of the unsprayed trees was lost, while the sprayed fruit suffered very little. This result is remarkably good for three applications, and such results can not be expected except after the most thorough work.

TABLE 4.—*Comparison of sound and bitter-rot affected fruit from sprayed and unsprayed trees of the Givens variety, Lincoln orchard, Bentonville, Ark., 1906. Fruit picked October 8 and 12.*

Date of spraying and tree number.	Yield.	Sound apples.	Diseased apples.	Percent- age of sound fruit.
Trees sprayed July 10 and 23 and August 9 and 27:	<i>Bushels.</i>	<i>Number.</i>	<i>Number.</i>	
No. 1.....	19.86	2,341	111	95.43
No. 2.....	21.52	3,102	69	97.82
No. 3.....	23.00	2,659	10	99.62
No. 4.....	16.02	1,922	8	99.58
No. 5.....	21.26	2,017	7	99.65
No. 6.....	17.82	2,271	26	98.80
Nos. 1 to 6 combined.....	119.48	14,312	231	98.41
Trees not sprayed:				
A.....	4.75	3	2,266	10
B.....	6.88	212	1,518	12.25
C.....	3.25	295	660	30.89
A, B, and C combined.....	14.88	510	4,444	10.29

The Givens, being a late-maturing variety, was not picked until October 8 and 12, two weeks later than the Ben Davis and six weeks later than the Jonathan. Therefore, in order to carry the crop through the season safely it was given an additional spraying on August 27. As seen in Table 4, the results were 98.41 per cent of sound fruit from the 6 sprayed trees and 10.29 per cent of sound fruit from the 3 unsprayed trees.

The above are four examples of almost complete protection against bitter-rot by the thorough application of Bordeaux mixture, and fully corroborate the results obtained in the experiments in the control of this disease conducted in Virginia in 1905. It would appear that there is no longer a reasonable excuse for the severe losses from this disease.

Cost of treatments.—In Captain Lincoln's orchard only 400 gallons of mixture were required for one spraying of 200 trees, and the work was accomplished with four men and one team in one-half day. The 40 pounds of bluestone at 8 cents a pound cost \$3.20 and the same amount of lime at one-half cent a pound cost 20 cents. The four men, at \$1.25 a day each, cost for the half day \$2.50, and the team cost \$1 for the half day. This aggregates \$6.90 for spraying 200 trees, or a little less than 3½ cents a tree for one application. This makes a total cost of 10½ cents a tree for the three applications given to the Jonathan, Gano, and Ben Davis trees, and 14 cents a tree for the four applications that the Givens variety received. This is the cost of the bitter-rot treatment alone; if the cost of the arsenate of lead used for protection against the codling moth be included, 1½ cents per tree for each application should be added.

It will be seen from the tables that the sprayed trees averaged upward of 4 barrels to a tree, but being only 10 years old and well pruned they were easily sprayed and the cost of treatment was less than would be required for older trees.

RECOMMENDATIONS.

Although excellent results were obtained from three sprayings in the case of the Jonathan, Gano, and Ben Davis varieties, experience elsewhere has shown that it is not always safe to rely on so small a number of applications. The work here was done just at the right time, except the late beginning on the Jonathan, and with a thoroughness that is not ordinarily secured in general orchard spraying. The first application was made dangerously late, so that only two subsequent sprayings were required to cover the infection period. In the treatment of a larger orchard, requiring a week or more to cover it, such a late beginning might prove disastrous.

It is therefore recommended that four sprayings at intervals of two to three weeks, beginning about six weeks after the petals fall, be made where bitter-rot alone is to be treated. In order to get the fruit thoroughly covered with the spray before infection takes place the second application should follow the first within two weeks, while the intervals between the subsequent applications may be extended to three weeks unless the season be unusually wet and warm. Bordeaux mixture, made of 5 pounds of bluestone and 5 pounds of lime to 50 gallons of water, seems best for this disease, but the 4-6-50 formula^a gives satisfactory results, especially where a larger number of applications are made for the combined treatment of bitter-rot and other troubles.

APPLE BLOTCH.

OCCURRENCE.

During the past several years the Department of Agriculture has received specimens of apples affected with a fungus (*Phyllosticta* sp.) causing blotches or spots, which so disfigure the fruit as to render it unmarketable. This disease has been variously known as "Phyllosticta," "black-scab," "late-scab," "cancer," and "fruit-blotch."

The records of the Department show that apples affected with this disease have been received from Virginia, Maryland, New Jersey, Ohio, Nebraska, Kansas, Missouri, Arkansas, Oklahoma, Indian Territory, and Texas. It has also been recorded from southern Illinois by Clinton.^b Although appearing to have rather a wide distribution, it has not attracted much attention. This is perhaps due largely to the fact that, except in a few localities, it has not been a serious pest and has generally been mistaken by the orchardists for the ordinary apple scab. This proved to be the case in some of the orchards selected for demonstration spraying, and it turned out as the season progressed that this was one of the serious fungous troubles from which the orchardists were seeking relief.

^a Four pounds of bluestone and 6 pounds of lime to 50 gallons of water.

^b University of Illinois Agric. Exp. Sta. Bul. 69, pp. 190-192, Pl. B, fig. 1.

DESTRUCTIVENESS.

The serious nature of apple blotch became apparent during the past season in southern Missouri and northwestern Arkansas, where 50 to 90 per cent of the apple crop was destroyed by it in a large number of orchards. During the month of September an examination of a dozen orchards in Benton County, Ark., showed the following estimated percentages of the crops affected by this disease:

Number of trees and percentage of affected fruit.

	Orchard number.											
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Number of trees.....	800	1,000	2,000	4,000	1,000	1,500	1,500	500	500	25,000	500	1,000
Percentage of affected fruit.....	50	40	80	75	90	90	50	15	90	75	80	75

These orchards are located at widely separated points in the county, and the table fairly represents the conditions that obtained in unsprayed orchards throughout that section. Where the injury ran over 75 per cent of the crop no attempt was made to pick and barrel the fruit. It was usually shaken off and taken to the evaporators. Practically all of the fruit affected with this disease was unfit for barreling, but the larger percentage of it made good evaporator stock.

The season was unusually wet, which may account in part for this serious outbreak. According to the statements of a number of prominent apple growers of Arkansas, the disease has been a serious pest in that State for at least four years, but the severity of the outbreak during the past season is probably unusual.

DESCRIPTION.

The disease known as blotch first appears on the surface of the apple as a small irregular brown spot, which slowly increases in size until, after several weeks, it reaches one-fourth to one-half inch in diameter. Although the general outline of the spot is circular the margin is broken and fringed, with a radiating appearance, suggesting the name "blotch." (See fig. 2.) When the diseased area reaches about one-eighth to one-fourth inch in diameter several raised points (fruiting bodies) appear at and near the center. These points are dark brown at the apex, shading off into a light brown at the base. As the disease advances these bodies become more numerous, and although arranged somewhat in groups they are scattered rather promiscuously over the blotch. In some instances these bodies may uplift the skin of the apple in such a way as to form drab-colored blisters. The diseased area is rather superficial and slightly depressed and the epidermis becomes very hard.

Several blotches may occur on the same fruit, and in the Ozarks during the past season it was not uncommon to find 20 to 50 blotches on a single apple, covering practically the entire surface. The tissues of the invaded area being dwarfed by the action of the fungus, further growth of the apple results in a cracking of the fruit similar to that produced by the apple scab fungus. The cracks range from one-fourth to 1 inch in length and frequently extend almost to the center of the apple. In extreme cases a crack may almost encircle the apple, practically dividing it in half, and one crack may intersect another, forming a cross. Fruits only slightly affected with the disease may go through the season without developing cracks. These are more commonly developed shortly before the fruit matures, though a few may occur earlier in the season. The skin being thus broken, the fruit becomes

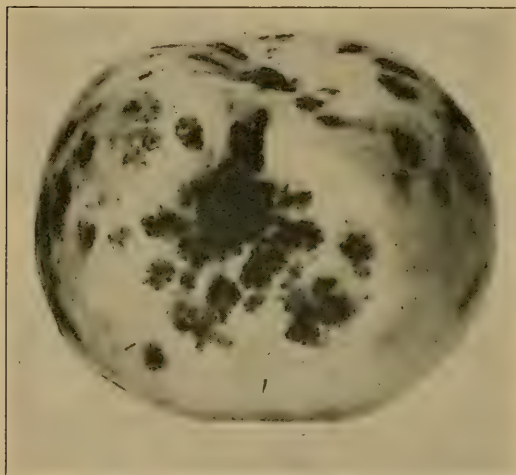


FIG. 2.—A Maiden Blush apple affected with apple blotch.
(Original.)

an easy prey to other fungi and soon goes down in decay. As a rule the affected fruit drops prematurely, and the unsprayed Ben Davis trees left as checks in the demonstration blocks at Bentonville, Ark., shed 50 per cent of their crop some days before picking time.

PERIOD OF INFECTION.

Infection does not begin to take place until the fruit is nearly half grown. The blotch was

first observed on the check trees June 26, and only a few affected fruits could be found on that date. On July 16 a large percentage of the Ben Davis apples was affected, and by the middle of August it was clearly seen that the crop was practically lost. It developed first on fruit on the lower branches and within the shaded portions of the tree, but finally spread to almost the entire crop.

THE CAUSE.

Apple blotch appears to be the same disease as that described from Illinois by Clinton^a as due to an undescribed fungus, belonging to the genus *Phyllosticta*. This fungus is under investigation by Messrs. Rorer and Scott, of the Bureau of Plant Industry, who expect to report on it at the end of another season.

^a University of Illinois Agric. Exp. Sta. Bul. 69, pp. 190-192, Pl. B, fig. 1.

DEMONSTRATION SPRAYING FOR APPLE BLOTCH IN ARKANSAS.

The treatment.—As stated above, the apple blotch appeared to a disastrous extent in some of the demonstration blocks. Excellent opportunities were, therefore, afforded for observing the effect of spraying with Bordeaux mixture in the control of this disease in connection with the spraying in the Gipple orchard at Bentonville, Ark. One hundred Ben Davis trees, 18 years old, fairly vigorous and in good condition, were used, of which number 24 trees were set aside as checks and left untreated. A block of 100 Winesap trees was also used in the demonstration work, but as the apple blotch did not develop to a serious extent on this variety, only the results obtained on the Ben Davis block will be reported here.

The trees were sprayed with Bordeaux mixture on May 4 (about four days after the petals had fallen), May 8, June 12, June 26, July 17, and August 4, making six applications in all. This orchard was reached late, and the two early applications were made only four days apart in order to thoroughly poison the fruit for the codling moth before the calyx lobes closed, and for protection against apple scab. The formula of Bordeaux mixture used was 4 pounds of blue-stone and 6 pounds of lime, with the addition of 2 pounds of arsenate of lead, to 50 gallons of water.

The results.—The crop was picked from September 19 to 27, and the fruit from each of the several sprayed and unsprayed trees was classified according to injury from scab, apple blotch, bitter-rot, black-rot, and the codling moth, the affected apples being counted in each case. The crop from the remaining trees, sprayed and unsprayed, was simply classified as merchantable and unmerchantable fruit, as shown later (p. 33). The windfalls were included in the counts, so that practically every apple produced by the trees was taken into account. The first count of windfalls was made on August 4 in order to get their classification before they decayed, and the fruit that fell subsequently was classified at the time the crop was harvested.

The results of the treatments in controlling the apple blotch are shown in Table 5.

TABLE 5.—*Comparison of sound fruit and fruit affected with apple blotch from 3 sprayed and 3 unsprayed Ben Davis trees, Gipple orchard, Bentonville, Ark., 1906. Fruit picked September 19 to 27.*

	Trees sprayed May 4, 8, June 12, 26, July 17, and August 4.				Trees not sprayed.			
	No. 1.	No. 2.	No. 3.	Nos. 1 to 3 combined.	A.	B.	C.	A, B, and C combined.
Total bushels.....	17.0	18.3	19.5	54.8	14.5	5.85	3.19	23.54
Number of sound apples.....	2,145	2,617	2,649	7,411	872	226	72	1,170
Number of diseased apples.....	140	320	254	714	1,887	853	568	3,308
Percentage of sound fruit.....	93.87	89.1	91.25	91.21	31.60	20.94	11.25	26.12

As shown in Table 5, about 90 per cent of the crop from the sprayed trees remained free from the apple-blotch disease, while about 75 per cent of the crop of the unsprayed trees was destroyed by it. This fairly represents the conditions as they existed throughout the block, as shown by the comparative commercial yield of the sprayed and unsprayed trees given later (p. 33). It will be noted, however, that in spite of the spraying nearly 10 per cent of the crop was affected, but the diseased spots were, as a rule, very small, and in many cases scarcely noticeable. They were mainly on apples that were on low-hanging branches, well in toward the trunk and protected from the spray by the outer branches. In cases where only one side of an apple was reached by the spray, owing to some obstruction, the spots developed on the unsprayed side. This emphasizes the importance of driving the mixture into all parts of the tree in order to spray every apple thoroughly. Since the period of infection is about the same as that of bitter-rot, it appears that the same treatment is applicable to both diseases. In connection with some bitter-rot experiments conducted in the same orchard, it developed that the early applications were not necessary for the control of apple blotch. In fact, trees that were sprayed May 4, May 8, June 12, and June 27 had 46.6 per cent of the crop affected with apple blotch, showing that these applications gave only slight protection against this disease.

RECOMMENDATIONS.

Make four applications of Bordeaux mixture at intervals of two weeks, beginning about six weeks after the petals fall. This corresponds exactly with the treatment for bitter-rot, and the two diseases may, therefore, be controlled with the same applications. However, as apple blotch seems rather more difficult to control than bitter-rot, in sections where severe outbreaks occur treatment should perhaps begin a week earlier and be continued later, making five applications in all. So far as the writers know, these are the first experiments in which this disease, when occurring on the fruit, has been successfully controlled.

LEAF-SPOT DISEASES.

There are several species of fungi that attack apple leaves, producing brown, circular spots that range from mere specks to spots one-fourth of an inch in diameter and in some cases much larger, as shown in figure 3. The disease may begin to appear in the spring soon after the young leaves unfold, but the spots are usually more prominent between midsummer and the end of the season. This diseased condition causes the leaves to drop prematurely, frequently leaving the trees denuded in early autumn, six weeks or two months before the

normal period of leaf fall. Trees thus deprived of their foliage cease activity, and as a result the fruit is small and not properly matured; the buds for the crop of the following year are weakened and in some cases not fully developed, and the life of the tree is materially shortened. These leaf diseases are partly responsible for the failure of the trees to produce crops and for the early decline of the orchard.

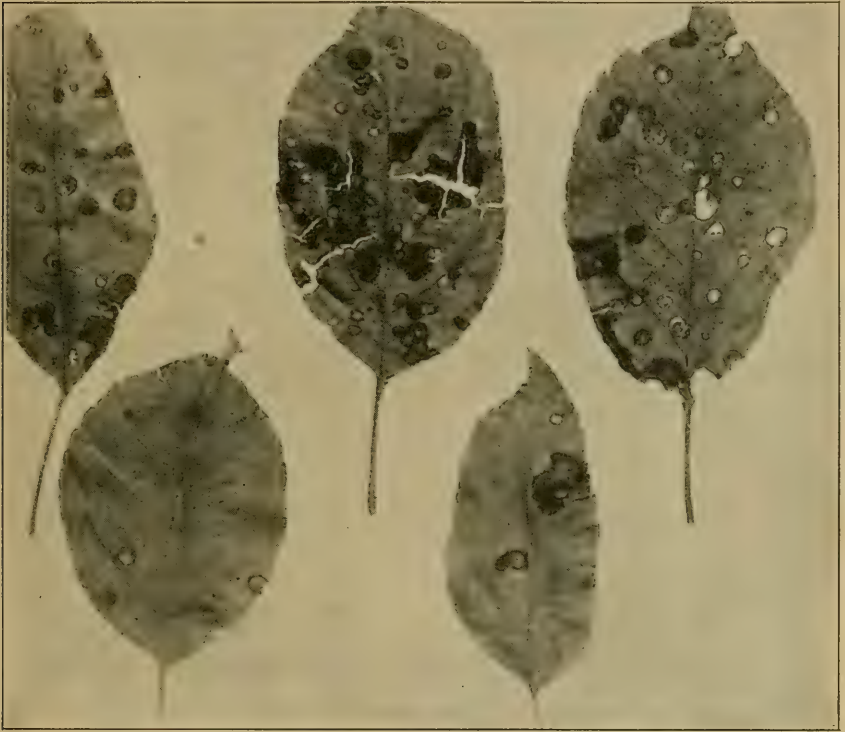


FIG. 3.—Apple leaves affected with leaf-spot diseases. (Original.)

THE CAUSE.

Leaf spots are due to several different fungi, perhaps the most prominent of which is a species of *Phyllosticta*. A species of *Hendersonia* and the ordinary black-rot fungus, *Sphærospora malorum*, are found in connection with some of these spots and may be responsible for the injury in some cases. Other fungi are also frequently present in the dead areas, and it is not always clear which are the real parasites.

RESULTS OF TREATMENT.

One of the most striking results of spraying an apple orchard is the effect on the foliage. These leaf diseases are largely prevented by applications of Bordeaux mixture, and the foliage remains fresh and

green long after unsprayed trees are defoliated. This was true of all the demonstration blocks in the Ozarks during the past season. The unsprayed trees began to shed their leaves in July and were practically defoliated by the last of August, a month before the time to pick the crop.

RECOMMENDATIONS.

The treatment recommended for bitter-rot and apple blotch will largely prevent these leaf troubles and hold the foliage in good condition until frost. It is true that some of the leaves become affected soon after they unfold in the spring, but the trouble does not usually become serious before midsummer, and the four applications of Bordeaux mixture for bitter-rot at intervals of two to three weeks, beginning about six weeks after the blossoms are shed, appear to give reasonable protection. However, the earlier applications usually necessary for the control of apple scab and the codling moth aid in the control of leaf-spot diseases, and when these are made, only one or two of the later sprayings are necessary. When it is desired to spray for leaf-spot diseases only, the first application should be made about two or three weeks after the petals have fallen, and a second about seven weeks later. These two applications, if thoroughly made, will usually hold the foliage in good condition.

APPLE SCAB.

INJURY.

The apple crop of the United States suffers a greater loss by far from the attacks of scab, caused by *Venturia inæqualis* (Cke.) Ader, than from any other fungous disease to which this fruit is subject. It often affects 50 to 75 per cent of the crop over wide areas, and is not infrequently responsible for total failures by killing the young fruits when in blossom or soon thereafter, and by rendering the fruit too unsightly for the market.

Scab has a wide distribution, being exceedingly serious in New England, the Middle Atlantic States, the Mississippi and Ohio valleys, and the Pacific Northwest. In these regions it is almost impossible to obtain crops reasonably free from scab without spraying. Indeed, so great is the damage done by this fungus and the codling moth that the percentage of strictly first-class fruit placed on the market is quite small, the great bulk of the crop, as a rule, being only second class.

DESCRIPTION.

The scabby spots that appear on the fruit are so familiar to apple growers that a description here is almost superfluous. They are circular, rough, somewhat irregular in outline, grayish or olive-green

in color, becoming black when older, and range in size from mere specks to spots one-fourth to one-half inch in diameter. Two or more spots may coalesce, forming large, irregular scabby areas. The ruptured skin of the apple usually persists around the margin of the spot, leaving a light-colored ring at the border of the healthy tissue.

Young fruits affected with this disease may become pitted, one-sided, and otherwise distorted, and in severe cases the fruit becomes cracked, as shown in figure 4. The fungus may attack and destroy the blossoms and even the unopened buds; the flower stalks may become so weakened by the disease that the young fruit drops off. The disease also appears on both sides of the leaves and on the leaf-stalks in the form of smoky brown patches, which become swollen and blister-like. It often causes the leaves to curl more or less and results in the premature shedding of the foliage. The scab first appears early in the spring on the young buds and unfolding leaves, and new infections may continue to take place throughout the season.

THE CAUSE.

Apple scab is due to the presence of the fungus *Venturia inaequalis* (Cke.) Ader, which grows beneath the cuticle of the leaves and fruit, invading the superficial cells with its branching threads. In a short time the fungus gives rise to groups of small stalks, which break through the cuticle, or skin, and give forth numerous minute olive-colored spores. These spores are blown about by the wind, and it is by means of these wind-dispersed spores that the infection takes place. The fungus is carried over winter in the diseased leaves on the ground, where spores of the perfect stage are produced, which are discharged in early spring as the young leaves and fruit buds begin to open. These winter spores start the infection, which is further spread by the summer spores, soon produced by the new scab spots.



FIG. 4.—Apples badly affected with scab.
(Original.)

RESULTS OF TREATMENT.

The treatment for apple scab has been known for a number of years. It was worked out fully by the Bureau of Plant Industry in 1891-1893 in experiments carried on in the State of New York. Certain progressive apple growers have known that thorough applications of Bordeaux mixture just before the trees bloom, and again as soon as the petals have fallen, will largely prevent this disease.

The scab was not serious in the Ozark region during the past season, and unsprayed trees showed but slight infections. On this account the results from spraying in the demonstration orchards are not considered of sufficient importance to present here. It may be worth while, however, to give some results in controlling scab obtained in the orchard of the Morton estate at Nebraska City, Nebr., in connection with a spraying experiment conducted by the Department of Agriculture during the past season, devoted to codling moth as well as scab.

There were 13 different plots of 6 trees each and 12 checks, but only plots 1 and 2 and the checks will be here considered, as these other plots were devoted primarily to the codling moth or were planned to show the danger of omitting treatment at critical periods. Plot 1 was sprayed first when the cluster buds were open, shortly before blooming (April 25), and again as soon as the petals had fallen (May 11). Plot 2 had the same applications and a third spraying on May 17. The 5-5-50 formula of Bordeaux mixture was used for the first application, and the 4-6-50 formula with 2 pounds of arsenate of lead for the succeeding applications. The results from 3 trees of each sprayed plot and 3 untreated trees are given in Table 6:

TABLE 6.—Comparison of sound and scabby fruit from sprayed and unsprayed winesap trees, Morton orchard, Nebraska City, Nebr., 1906. Fruit picked Oct. 20.

Tree.	Total quantity.	Sound apples.	Diseased apples.	Percentage of sound fruit.
Plot I: <i>a</i>	<i>Bushels.</i>	<i>Number.</i>	<i>Number.</i>	
No. 1.....	22	5,157	145	97.26
No. 2.....	18	4,591	128	97.28
No. 3.....	13.5	3,345	33	99.02
Nos. 1, 2, and 3 combined.....	53.5	13,093	306	97.71
Plot II: <i>b</i>				
No. 1.....	18	4,607	46	99.01
No. 2.....	15	4,256	11	99.74
No. 3.....	14	4,057	51	98.78
Nos. 1, 2, and 3 combined.....	47	12,920	108	99.17
Check: <i>c</i>				
No. 1.....	11	971	1,949	33.25
No. 2.....	12	1,297	1,890	40.69
No. 3.....	16	1,309	2,626	33.26
Nos. 1, 2, and 3 combined.....	39	3,577	6,465	35.62

a Sprayed April 25, when cluster buds opened; May 11, as petals fell.

b Sprayed April 25, when cluster buds opened; May 11, as petals fell; May 17, six days after petals fell.

c Unsprayed.

As has been abundantly demonstrated in the past, these results again show that apple scab can be readily controlled by applications of Bordeaux mixture. It is seen in Table 6 that Plot I, which had two applications, yielded 97.71 per cent of sound fruit, and that Plot II, which received three applications, gave 99.17 per cent of sound fruit. In this case the third application was of very little additional benefit; but if the second spraying is not thoroughly done a supplemental treatment a few days later is quite important. It should be understood, however, that these results, obtained from two or three sprayings, apply only west of the Missouri River. In the more humid sections to the eastward, especially around the Great Lakes, in a wet spring 5 or 6 treatments are necessary.

RECOMMENDATIONS.

Spray with Bordeaux mixture, 5-5-50 formula, when the cluster buds are open but before blooming, and again as soon as the petals have fallen. If the second application has not been very thorough, a third should be made seven to ten days later. In case of a wet spring three sprayings are usually necessary.

THE CODLING MOTH.

The larva of the so-called codling moth (*Carpocapsa pomonella* L.) is by far the most serious of the insect pests which affect the apple. The losses due to its work equal if they do not exceed the losses from all other insect pests of this crop combined. In unsprayed orchards throughout the country from one-half to three-fourths of the crop is destroyed, entailing a loss of millions of dollars annually. A large percentage of this loss is preventable, as has been known for many years, and a large number of orchardists practically control the insect by timely and thorough work with sprays. Indeed, the codling moth is perhaps more satisfactorily controlled than most other insect pests of the apple, such as apple-tree borers, the apple maggot, the plum curculio, scale insects, and the wooly apple aphis. Notwithstanding the large amount of testimony from experimenters and practical orchardists as to the advantages of spraying, there are yet many growers who take no steps to control the pest or who secure only indifferent results from lack of knowledge of the insect itself and of the requisites for successful control work.

CHARACTER OF INJURY.

Wormy apples (see fig. 5) are familiar to all growers and consumers of this fruit, and many have seen, upon cutting open an apple, the small, pinkish larva, about three-fourths of an inch long, the cause of all the mischief. The greater part of the life of the larva is spent

within the fruit, during which period it feeds freely on the substance of the apple, eating out a cavity or tunnel and pushing out from the entrance hole a considerable quantity of powdery brown frass. Most apples injured when small, as by larvæ of the first generation, drop from the trees, and these often constitute a large percentage of the so-called windfalls. Larvæ of the first generation will mostly enter the fruit at the blossom end, some, however, entering at the side, as where two fruits are in contact or where an apple is touched by a leaf. Larvæ of the second generation enter the fruit more from the side than the calyx end, and by reason of their greatly increased numbers cause the larger part of the total injury. In localities where a third or partial third brood may occur, the habits of this generation are no doubt practically identical to those of the second.

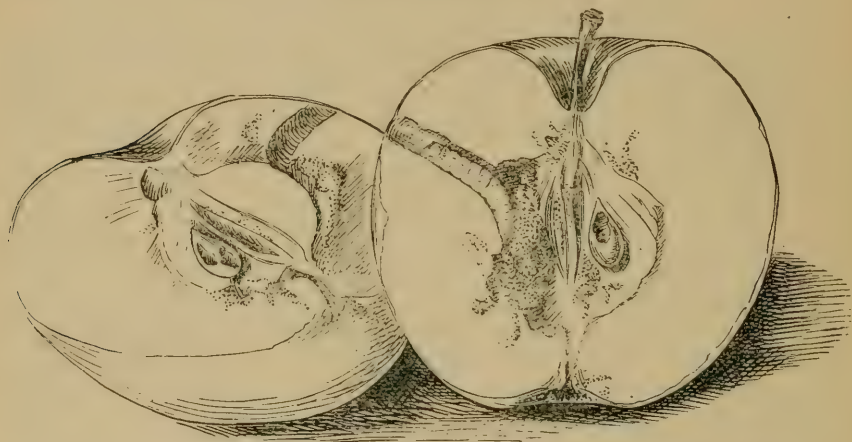


FIG. 5.—A wormy apple, showing a mature codling moth larva and its work. (Original.)

DESCRIPTION AND LIFE HISTORY.

How the insect passes the winter.—In late summer or fall larvæ seek protected places upon the trees, as holes, cracks, crotches of limbs, or under bark scales, or even underneath trash on the ground, construct tough silken cocoons, and here pass the winter in the larval condition. Large numbers of larvæ are carried to storage houses in apples in the fall, where later they spin cocoons in the boxes, bins, or barrels, or in cracks in the floor or sides of the house. In the orchard large numbers of larvæ are destroyed during winter by birds, principally woodpeckers, but in storage houses a large proportion doubtless survives, the moths from which fly to the orchards in the spring and constitute an important source of infestation.

With the coming of spring the larvæ enter the pupal stage, and later, about the period of blooming of the apple, the moths begin to

appear, continuing to emerge for three or four weeks, while belated moths may not emerge until considerably later.

The moth.—The adult, or miller, (fig. 6, *a, f*) is rather variable in size, but the maximum wing expanse rarely exceeds three-fourths of an inch. The forewings above are of a brownish gray color, with numerous cross lines of gray. Near the tip of each wing is a conspicuous brown spot, or ocellus, in which are two irregular broken lines of a metallic coppery or golden color. The hind wings above are grayish brown, becoming darker toward the margin, which bears a delicate fringe, at the base of which is a narrow dark line. When at rest on the grayish bark of an apple tree, the color of the moth so harmonizes with its surroundings that it is not readily distinguished, and the insect in this stage is perhaps but little known to orchardists.

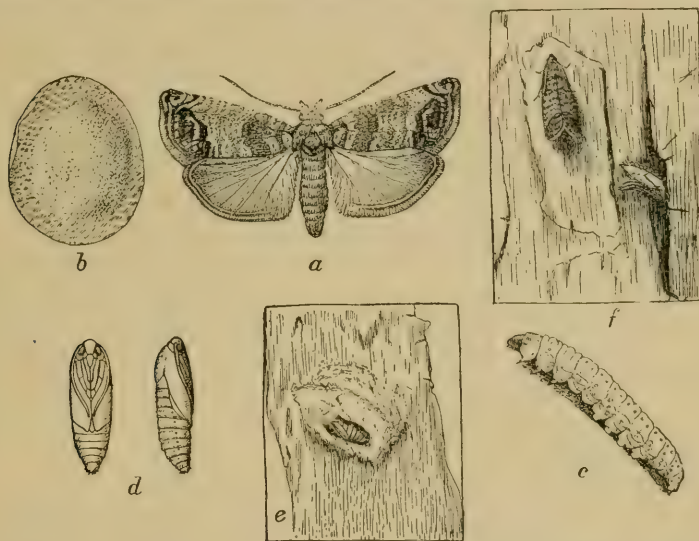


FIG. 6.—Stages of the codling moth: *a*, the moth or adult insect, slightly enlarged; *b*, the egg, greatly enlarged; *c*, the full-grown larva, slightly enlarged; *d*, the pupa, slightly enlarged; *e*, the pupa in its cocoon on the inner surface of a piece of bark, reduced about one-half; *f*, moth on bark and empty pupa skin from which it emerged, about natural size. (From Simpson.)

Shortly after emerging (fig. 6, *f*), the sexes mate and the females begin the deposition of eggs, the number for one individual, as stated in the literature regarding this insect, averaging about 50.

The egg.—The eggs are small, flat, somewhat oval in shape, of about the size of a pinhead. When recently deposited they are of a pearl-white color, but become darker with the development of the embryo, which after a few days is easily distinguished as a reddish ring within the egg. Under a lens the surface is seen to be covered with a network of ridges (fig. 6, *b*), coarser toward the edge. The eggs of the first generation of moths are deposited mainly on the leaves

and twigs, comparatively few being placed on the apple, possibly on account of the fine hairs with which it may be more or less covered when small. The majority of the eggs of the second generation, however, are placed on the fruit, which by this time is much larger and presents a comparatively smooth surface. The average time required for the egg to hatch is about eleven days, the time varying considerably, however, with temperature.

The larva.—It is in the larval or "worm" stage that injury is done to the apple. The larva as it hatches from the egg is very small, from one-twentieth to one-sixteenth of an inch in length, and soon begins to search for the fruit. If hatched from eggs placed here and there on the foliage, the larvæ chew more or less into the leaf or other portions of the plant in their wandering around, and may thus be poisoned if poison be present on the plants. If the eggs have been deposited on the fruit itself the larvæ are much more likely to gain entrance to the fruit. Larvæ entering the fruit by the calyx end feed within the calyx cavity for a few days before penetrating the fruit, and hence the advantage of thoroughly spraying trees shortly after the petals have fallen and while the calyx lobes are still spread, in order to place in each calyx cavity a small particle of poison to be later eaten by the little larva as it seeks to enter the fruit.

After entering the apple the larva feeds and grows rapidly and in the course of about twenty days has become full grown. At this time the insects are about three-fourths of an inch long, and the majority of them are pinkish or flesh colored on the upper surface and whitish below. The head is brown and well developed, and there are 8 pairs of legs, the 3 pairs of true legs on the thorax and 5 pairs of prolegs on the abdomen (fig. 6, *c*).

When ready to leave the fruit the larva eats out a hole at the side, or, less usually, makes its exit by enlarging the entrance hole. If the infested apple is hanging on the tree the larva usually makes its way out to the limb and thence crawls down the branches to the trunk until a suitable place for pupation is found. If the apple has fallen before the larva has gotten its growth the latter simply crawls to a convenient place and there constructs a cocoon.

The pupa.—The full-grown larva, upon leaving the fruit and finding a protected place, constructs a whitish silken cocoon (fig. 6, *e*) within which in the course of a few days it may change to pupa or may remain in the larval condition until the following spring, as explained under the next heading. The pupa (fig. 6, *d*) is about one-half inch long, at first yellowish or brownish, but later becoming quite dark brown, and shortly before the emergence of the moth assuming a distinct bronze color. This stage varies much in length, but on the average about twenty days elapse from the spinning of the cocoon

until the emergence of the moth. After emergence the moths in the course of a few days begin egg laying, the entire life cycle from egg to egg requiring, on the average, some fifty days.

GENERATIONS OF THE INSECT.

The number of generations of the codling moth in a season varies with the latitude and region. In the more Northern States, as in Maine and New York, there is but one generation each year, with often a rather light partial second, the size of the second generation varying with the season. In the upper tiers of Middle Eastern and Western States, as New Jersey, Ohio, and Iowa, the second generation will be more nearly a full one. In States of the latitude of Virginia, Kentucky, Kansas, and Colorado there will be two full generations, while in the extreme South and Southwest and portions of the West a partial third generation is thought to occur. Injury from the second brood is much greater than from the first and, unfortunately, more difficult to prevent.

As stated, moths of the first or overwintering generation will begin to emerge about the time apple trees are in bloom, continuing for some weeks, the date varying according to locality and season. The moths of the second generation may begin to appear fifty to sixty days from the blooming period, though their maximum abundance will be somewhat later. The first and second generations will overlap, so that larvæ are to be found in the fruit practically throughout the season. In the Ozarks, moths of the second generation are coming out in some numbers by about July 15, the number increasing throughout late July and early August.

DEMONSTRATION SPRAYING FOR THE CODLING MOTH.

In spraying with Bordeaux mixture for the fungous diseases of the apple previously mentioned, an arsenical was always added for the control of the codling moth. In securing results the drop apples were collected from the ground and examined as to freedom from or injury by the codling moth, and the crop from the trees at picking time was similarly graded. In some cases the fruit was simply measured; in others it was actually counted.

Results in Arkansas.—In the Gipple orchard at Bentonville four trees in the Ben Davis block sprayed for bitter-rot and apple blotch were selected for obtaining data on the effect of the treatments for the codling moth. The arsenical used was arsenate of lead at the rate of 2 pounds to 50 gallons of Bordeaux mixture, and applications were made on May 4, May 8, June 12, June 26, July 16, and August 4, making six treatments in all. The first two applications, on May 4 and May 8, immediately after the petals had fallen—perhaps the

most important of all treatments—were far from satisfactory, efficient spraying apparatus not then being available. Subsequent applications, however, were quite thorough, and the trees and fruit were kept fairly well coated with the spray during the remainder of the season. The orchard under experiment, however, was joined on two sides by orchards which were not sprayed and which served as sources of reinfestation, the moths undoubtedly flying into the treated orchard from the untreated ones. Injury from the second brood of the codling moth was therefore greater than would probably have been the case had the adjacent orchards received proper treatment.

The fruit from four untreated trees in the bitter-rot check was also classified in regard to codling moth injury, to serve as a basis for comparison with the sprayed trees. The yield of sound and wormy fruit from the eight trees is detailed in Table 7.

TABLE 7.—Comparison of sound and wormy fruit from four Ben Davis trees sprayed with Bordeaux mixture and arsenate of lead and from four unsprayed trees, Gipple orchard, Bentonville, Ark., 1906. Fruit picked September 19 to 27.

Date of spraying and tree numbers.	Total crop.	Windfalls.			Fruit from tree.			Total number of apples.	Percentage of sound fruit.
		Wormy.	Not wormy.	Total.	Wormy.	Not wormy.	Total.		
Sprayed May 4, May 8, June 12, June 26, July 16, and Aug. 4:									
Tree 1.....	17	41	86	127	108	2,050	2,158	2,285	93.5
Tree 2.....	13.1	82	167	249	117	1,433	1,551	1,800	88.8
Tree 3.....	19.56	167	337	504	270	2,129	2,599	2,903	84.9
Tree 4.....	18.33	143	244	387	215	2,335	2,550	2,937	87.8
Trees 1 to 4 combined.....	67.99	433	834	1,267	710	7,947	8,858	9,925	88.4
Unsprayed:									
Check A.....	14.5	799	454	1,253	906	595	1,501	2,754	38.8
Check B.....	5.59	195	97	292	421	342	763	1,055	41.6
Check C.....	3.19	200	120	320	224	96	320	640	33.7
Check D.....	5.85	336	139	475	371	233	604	1,079	34.4
A, B, C, and D combined.....	29.13	1,530	810	2,340	1,922	1,266	3,188	5,528	37.5

It will be seen that the average percentage of sound fruit from the four sprayed trees is 88.4, and from the four unsprayed trees 37.5, a gain in fruit free from codling moth injury of 50.9 per cent.

Results in Missouri.—Demonstration work at Fordland, Mo., was carried out in the orchard of Mr. J. E. Hansell, in a block of trees from 10 to 12 years old, including the Gano, Jonathan, and Ben Davis varieties.

Gano.—Plot 1, of 14 trees, was sprayed with Bordeaux mixture and arsenate of lead at the rate of 2 pounds to 50 gallons.

Plot 2, of 16 trees, was sprayed with Bordeaux mixture and Paris green at the rate of 1 pound to 150 gallons.

A block of 15 trees was left untreated as a check.

Applications were made on the following dates: April 20, May 7, May 16, June 8, June 26, July 17, and August 11, making a total of seven, of which, however, only six are to be considered as in any way affecting the codling moth, the treatment on April 20 being for scab and before the trees had bloomed.

The second application was made just after the petals fell from the blossoms and the third nine days later. These two, made while the calyx lobes of the young apples were still spread, were for the purpose of filling the calyx cavities with poison, and they were also important treatments for the apple scab.

The fourth application, on June 8, was designed especially to poison the foliage and fruit to destroy the codling moth larvæ, which it was thought would be hatching in considerable numbers at about that time.

The three subsequent applications were for the control of bitter-rot, leaf-blight, and the second brood of the codling moth. The results are shown in Table 8.

TABLE 8.—Comparison of sound and wormy fruit from Gano trees sprayed and unsprayed, Hansell orchard, Fordland, Mo., 1906.

Plot, date of spraying, and tree number.	Total crop.	Windfalls.			Fruit from tree.			Percentage of sound fruit.
		Wormy.	Not wormy.	Total.	Wormy.	Not wormy.	Total.	
Plot 1, sprayed April 20; May 7, 16; June 8, 26; July 16; August 11:								
Tree 1.....	Bush. 11.76	Bush. a 0.017	Bush. 0.5	Bush. 0.51	Bush. 0.25	Bush. 11	Bush. 11.25	97.7
Tree 2.....	5.81	b .005	.25	.255	c .055	5.5	5.555	98.9
Trees 1 and 2 combined.....	17.57	.022	.75	.765	.305	16.5	16.805	98.1
Plot 2, sprayed April 20; May 7, 16; June 18, 26; July 17; August 11:								
Tree 1.....	13.419	.044	.75	.794	.125	12.5	12.625	98.7
Tree 2.....	6.464	0	.42	.42	.044	6	6.044	97.7
Trees 1 and 2 combined.....	19.88	.044	1.17	1.21	.169	18.5	18.669	98.4
Check plot, unsprayed:								
Tree 1.....	5.045	.42	.125	.545	2	2.5	4.5	52.03
Tree 2.....	10.875	.75	.5	1.25	4.125	5.5	9.625	55.17
Trees 1 and 2 combined.....	15.92	1.17	.625	1.795	6.125	8	14.125	54.1

a 3 apples.

b 1 apple.

c 10 apples.

The average yield of sound fruit of the two trees of Plot 1 which received Bordeaux mixture and arsenate of lead is 98.1 per cent, and from the two trees of Plot 2, treated with Bordeaux mixture and Paris green, 98.4 per cent. The average yield of sound fruit from the two untreated trees is 54.1 per cent, there being a gain in sound fruit from the sprayed trees of 44 per cent.

Ben Davis.—In each of Plots 1 and 2 of the Gano block, and in an additional plot (Plot 3) were a few trees of the Ben Davis variety

which were sprayed along with the Gano, as previously stated. Plot 3 received the same treatment as Plot 2, except that the application on June 8 was omitted. The fruit from one Ben Davis tree of each of these plots, as well as from three unsprayed Ben Davis trees, was examined and classified by counting with respect to codling moth injury, and the results are detailed in table 9.

TABLE 9.—Comparison of sound and wormy fruit from three trees sprayed with Bordeaux mixture and arsenicals, and from three unsprayed trees of the Ben Davis variety, Hansell orchard, Fordland, Mo., 1906.

Date of spraying and tree number.	Total yield.	Windfalls.			Fruit from tree.			Total number of apples.	Percentage of sound fruit.
		Wormy.	Not wormy	Total.	Wormy.	Not wormy.	Total.		
Sprayed Apr. 20; May 7, 16; June 8, 26; July 17, and Aug. 11:									
<i>Bush.</i>		<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	
Tree 1.....	14	20	168	188	153	1,754	1,907	2,095	91.7
Tree 2.....	13.25	11	91	102	129	1,605	1,734	1,836	92.3
Tree 3 ^a	13.75	26	52	78	206	1,562	1,768	1,846	87.4
Trees 1, 2, and 3 combined.....	41	57	311	368	488	4,921	5,409	5,777	90.5
Unsprayed:									
Check 1.....	11.75	464	38	502	1,258	383	1,641	2,143	19.6
Check 2.....	6.875	224	24	248	697	488	1,185	1,433	35.7
Check 3.....	5.50	315	89	404	564	428	992	1,396	37.0
Trees 1, 2, and 3 combined.....	24.125	1,003	151	1,154	2,519	1,299	3,818	4,972	29.1

^a Treatment on June 8 omitted.

The three sprayed trees show an average percentage of sound fruit of 90.5 as against 29.1 per cent, the average percentage of sound fruit from the three unsprayed trees. This is a gain of 61.4 per cent for the treated trees.

Jonathan.—In a block of about 400 Jonathan trees used in some spraying experiments in the Hansell orchard at Fordland were three plots comprising 49 trees which received the demonstration treatment. These were sprayed with Bordeaux mixture and Paris green, 1 pound to 150 gallons, on the following dates: April 19, May 3, May 12, June 7, June 26, July 17, and August 11. The first application, April 19, for scab, was without effect in controlling the codling moth. Near each end of the block of 400 trees two adjacent rows were left untreated as checks, comprising in all 70 trees. The trees in this block are about 11 years old and small for their age. The orchard had had but little attention since 1901, and the crop of fruit was very light.

The effect of the treatments in controlling the codling moth is shown by the figures from 6 sprayed and 6 unsprayed trees presented in Table 10.

TABLE 10.—*Comparison of sound and wormy fruit from trees sprayed with Bordeaux mixture and Paris green, and from six unsprayed trees of the Jonathan variety, Hansell orchard, Fordland, Mo., 1906.*

Date of spraying and tree number.	Total yield.	Windfalls.			Fruit from tree.			Percentage of sound fruit.
		Wormy.	Not wormy.	Total.	Wormy.	Not wormy.	Total.	
Sprayed Apr. 29; May 3, 12; June 7, 26; July 17; Aug. 11:	<i>Bush.</i>	<i>Bush.</i>	<i>Bush.</i>	<i>Bush.</i>	<i>Bush.</i>	<i>Bush.</i>	<i>Bush.</i>	<i>Bush.</i>
Tree 1.....	4.37	<i>a</i> 0.02	0.25	0.27	0.10	4	4.10	97.2
Tree 2.....	2.24	0	.12	.12	.12	2	2.12	94.6
Tree 3.....	3.96	<i>b</i> .01	.37	.38	.08	3.5	3.58	97.7
Tree 4.....	1.77	0	.25	.25	.02	1.5	1.52	98.8
Tree 5.....	3.27	<i>c</i> .03	.37	.40	.25	2.62	2.87	91.1
Tree 6.....	6.14	<i>d</i> .02	.37	.62	.25	5.5	5.75	95.6
Trees 1 to 6 combined.....	21.75	.08	1.73	2.04	.82	19.12	19.94	95.8
Unsprayed:								
Tree 1.....	4.62	.25	.87	1.12	1.5	2	3.5	62.1
Tree 2.....	.99	.12	.12	.24	.25	.5	.75	62.6
Tree 3.....	4.48	.62	.37	.99	1.12	2.37	3.49	61.1
Tree 4.....	4.62	.5	.25	.75	.62	3.25	3.87	75.7
Tree 5.....	2.86	.62	.12	.74	.62	1.5	2.12	56.6
Tree 6.....	4.25	1	.25	1.25	.75	2.25	3	58.8
Trees 1 to 6 combined.....	21.82	3.11	1.98	5.09	4.86	11.87	16.73	63.4

a 5 apples.

b 3 apples.

c 8 apples.

d 6 apples.

It will be seen that the average yield of fruit free from codling moth injury from the 6 sprayed trees was 95.8 per cent as against 63.4 per cent of uninjured fruit from the 6 unsprayed trees, being a gain of 32.4 per cent.

It will have been noticed that in the work in Fordland, Mo., the percentage of codling moth injury to fruit from the treated trees was appreciably less than in the work at Bentonville, Ark. As explained in regard to the treated orchard at the latter place, this was bordered on two sides by large orchards which received no treatment during the season and which without doubt served as sources of reinfestation for the treated trees. The orchard at Fordland, on the other hand, was isolated, except for one orchard bordering it on the north, which received treatment for the codling moth.

The codling moth is best controlled when all of the orchards of a neighborhood are sprayed, and uniformity in this particular on the part of orchardists should be secured if possible.

RECOMMENDATIONS.

The first treatment for the codling moth should be made immediately after the blossoms fall. In this application the aim should be to place, as nearly as possible, a particle of the poisoned spray in the calyx cavity of every apple. At this time the little apples are mostly upright on the stems, and more effective work may be done by spraying from above, directing the spray downward. Long extension rods are indispensable, and for this application an elbow fitting between

the end of the rod and nozzle to better deflect the spray may often be used with advantage, or the chamber portion of the nozzle may be turned so that the spray will be directed at a right angle to the axis of the extension rod. One man at least, who should give special attention to treating the higher parts of the trees, should be on an elevated platform rigged upon the spray wagon. This is without doubt the most important of all of the applications for the codling moth, and some growers find it profitable to respray the trees at once after the first application has been finished and before the calyx lobes close, to further insure that the calyx end of each apple shall contain a particle of poison.

The second application for the codling moth should be made about three or four weeks from the dropping of the blossoms. The eggs of the first brood are hatching about this time in maximum numbers, and as they are mostly deposited on the foliage and twigs the resulting larvæ will feed more or less on these parts before gaining entrance to the fruit. Thorough spraying of foliage and fruit at this time will undoubtedly destroy many of these larvæ. If the first and second treatments have been thoroughly made, subsequent treatments are sometimes not necessary, especially if there is no danger of reinfestation from outside unsprayed orchards.

The first and second treatments may always be combined with the applications of Bordeaux mixture for apple scab. Where spraying with Bordeaux mixture is done for leaf-spot diseases, apple blotch, or bitter-rot, arsenicals should always be added for the second brood of the codling moth, and where injury from the first brood has not been satisfactorily prevented it will pay to spray for the second brood of the moth, irrespective of other considerations.

The third treatment for the codling moth (first treatment for second brood) should be made in ten weeks from the falling of the blossoms, and a fourth application should be given two or three weeks later.

COMMERCIAL RESULTS.

RESULTS IN ARKANSAS.

In addition to showing the effect of the treatments in controlling the respective diseases and the codling moth, as detailed in the foregoing pages, the fruit from a considerably larger number of trees in each of the demonstration orchards was classified into marketable fruits and culls, the culls including all fruit showing damage from the affections under consideration, all windfalls, and perfect fruit too small or too green for packing.

In the Gipple orchard at Bentonville, the crop from 47 trees of the sprayed block of Ben Davis trees was picked and classified on the sorting table, yielding the following results:

Merchantable fruit.....	bushels..	408
Culls (including windfalls).....	do....	98.75
Percentage of merchantable fruit.....		80.5

The crop from 17 untreated Ben Davis trees in the same block was similarly sorted, and gave results as follows:

Merchantable fruit.....	bushels..	7
Culls (including windfalls).....	do....	90.7
Percentage of merchantable fruit.....		7.2

It will be seen that of the crop from the unsprayed trees, 97.7 bushels, only 7 bushels were merchantable. In practice, the cost of labor for gathering and sorting such fruit would be more than its value, and the crop from the unsprayed trees would be, therefore, practically a complete loss, except for cider or evaporation.

In the same orchard the fruit from a block of 69 sprayed Winesap trees was sorted, as in the case of the Ben Davis, yielding—

Merchantable fruit.....	bushels..	255
Culls (including windfalls).....	do....	36.5
Percentage of merchantable fruit.....		87.4

The crop from 10 unsprayed Winesap trees yielded as follows:

Merchantable fruit.....	bushels..	6.75
Culls (including windfalls).....	do....	10.25
Percentage of merchantable fruit.....		39.7

The fruit classed as merchantable on the unsprayed Winesaps, namely, 6.75 bushels, was notably smaller than on the sprayed trees, 731 apples being required to fill a barrel as against 612 apples from the treated trees.

RESULTS IN MISSOURI.

In the Hansell orchard at Fordland, Mo., the fruit from 49 sprayed Jonathan trees, when classified, gave the following results:

Merchantable fruit.....	bushels..	121.5
No. 1's.....	do....	108
No. 2's.....	do....	13.5
Culls (including windfalls).....	do....	11.29
Percentage of merchantable fruit.....		91.4

From 34 unsprayed Jonathans the yield was—

Merchantable fruit.....	bushels..	51
No. 1's.....	do....	24
No. 2's.....	do....	27
Culls (including windfalls).....	do....	39.6
Percentage of merchantable fruit.....		56.2

Practically all the injury was due to the codling moth.

In the same orchard the fruit from 39 sprayed Gano trees gave results as follows:

Merchantable fruit.....	bushels..	258
No. 1's.....	do.....	207
No. 2's.....	do.....	51
Culls (including windfalls).....	do.....	37.37
Percentage of sound fruit.....		87.3

From 14 unsprayed Gano trees the yield was as follows:

Merchantable fruit.....	bushels..	42
No. 1's.....	do.....	21
No. 2's.....	do.....	21
Culls (including windfalls).....	do.....	39.5
Percentage of sound fruit.....		51.5

MATERIALS FOR SPRAYING.^a

Bordeaux mixture with an arsenical added is the most effective treatment for the principal diseases of the fruit and foliage of the apple and for the codling moth. This combined fungicide and insecticide intelligently applied to the trees in the form of a spray should enable the orchardist to protect from the attack of these pests from 85 to 95 per cent of his crop, as has been demonstrated by these tests and shown in the earlier pages of this bulletin.

BORDEAUX MIXTURE.

Bordeaux mixture is composed of copper sulphate (bluestone) and quicklime, with a certain quantity of water. The amounts of copper sulphate and of lime to be used with a given quantity of water vary somewhat, according to the kind of plants or trees to be sprayed and the disease to be treated. When used on the apple the following formula is quite satisfactory for general orchard work:

Copper sulphate (bluestone).....	pounds..	5
Quicklime.....	do.....	5
Water to make.....	gallons..	50

The foregoing formula was used throughout the bitter-rot work in the Lincoln orchard, but a weaker mixture composed of 4 pounds of bluestone and 6 pounds of lime to 50 gallons of water was mostly used in all the other orchards, in the belief that the latter would be less injurious to fruit and foliage; this, however, did not prove to be the case.

^a For a fuller discussion of fungicides and their preparation and types of spray outfits, see Farmers' Bulletin No. 243, entitled "Fungicides and Their Use in Preventing the Diseases of Fruits," by M. B. Waite. Also, for a discussion of insecticides and their use, see Farmers' Bulletin No. 127, "Important Insecticides," by C. L. Marlatt.

Directions for making.—If large quantities of Bordeaux mixture are to be used, stock solutions of the bluestone and lime should always be prepared, thus saving the time necessary to dissolve the materials. A stock solution of the copper sulphate may be made by dissolving it at the rate of 1 pound to each gallon of water. Fill a 50-gallon barrel two-thirds or three-fourths full of water, and place a sack (or box with perforations in the bottom and sides) containing 50 pounds of copper sulphate in the upper part of the barrel, suspending it by a string or copper wire. In from twelve to twenty-four hours the sulphate will have entirely dissolved, and the sack or box should be removed and enough water added to fill the barrel. After slight stirring, the solution is ready for use. The stock lime may be prepared by slaking 50 pounds in a barrel or other vessel, and finally adding water to make 50 gallons. In slaking the lime, sufficient water should be used to prevent burning, but not enough to drown it, and the mass should be continually stirred with a shovel or spading fork until a thin paste is formed. Stock preparations of both the lime and bluestone may, during warm weather, be prepared at twice this strength, that is, 2 pounds to each gallon of water, but it is difficult to slake more than 50 pounds of lime in a barrel, and when a larger quantity is to be prepared a box in which the lime may be spread out should be used. Barrels containing stock solutions should be kept tightly covered to prevent as much as possible the evaporation of the water, which would give a more concentrated stock solution. Preparatory to use, any water known to have been lost by evaporation should be added, to maintain the proper strength. In making Bordeaux mixture take the necessary quantities of the stock copper sulphate and the stock lime solutions to give the formula in the total amount of water to be used, and place each in separate elevated dilution tanks, which should hold half as much as the total capacity of the spray tank. Thus, if the spray tank holds 200 gallons each dilution tank should hold 100 gallons, and according to the above formula 20 pounds of copper sulphate (20 gallons of the stock solution) and 20 pounds of lime (20 gallons of the stock solution) would be required. To each dilution tank, water should be added (one-half the total amount of spray) and, after stirring, the diluted ingredients are allowed to run through separate hose or troughs attached to faucets at or near the bottom of the tanks, into the strainer on the spray tank, where the two solutions come together, producing the Bordeaux mixture; or, the diluted solutions may be run directly into a mixing tank alongside, the Bordeaux mixture being conducted thence by a hose directly to the spray tank. In extensive operations the latter method is perhaps to be preferred, as more than one batch of the Bordeaux mixture may be prepared somewhat in advance of the arrival of the spray wagon, effecting a slight saving in

time. Only the quantity which can be used during the day should be mixed, as the Bordeaux mixture deteriorates on standing.

In case the dilution tanks are not elevated to admit of filling the spray tank by gravity, the diluted solutions must be dipped and poured into the latter by hand, a bucketful of each simultaneously. This method is only advisable in small operations, where a few barrels at most are needed.

The stock solutions should never be poured together before being diluted, as a coarse, heavy, unreliable mixture will result instead of the light, flocculent preparation that characterizes properly made Bordeaux mixture.

It is important that Bordeaux mixture should be thoroughly strained in order to keep out any coarse particles that would clog the spray nozzles, and it is a good practice to strain the stock solution of lime upon pouring it into the dilution tank. The best material for a strainer is brass wire netting of about 20 meshes to the inch.

Mixing platform for Bordeaux mixture.—In the preparation of Bordeaux mixture in any considerable quantities, some form of elevated platform is almost indispensable, so that the diluted solutions or the mixture may be conducted by gravity directly to the spray tank on the wagon. The platform should be amply large to accommodate the necessary barrels and tanks (at least 10 by 12 feet). Strong and durable materials should be used in its construction, and a well-made platform should last for several years.

The water supply.—An ample water supply will often be at hand in or near the orchard, and the mixing platform must be constructed convenient to it. A supply through pipes or from a water tank is a desirable part of the outfit. The water tank may be separate, as on a windmill tower, or may be placed on the mixing platform above the level of the top of the dilution tanks.

This may be kept filled with a hand pump, but preferably with a pump run by windmill or other form of power. By these means the dilution tanks are most conveniently filled. A cheaper but less convenient way is to pump the water directly from a well, spring, or pond into the dilution tank. If a hillside is available it will be convenient to construct the platform against the hill, a road being made on the lower side as a driveway for the spray wagon, while the chemicals may be delivered at the upper side. A good spring of water, somewhat above the platform, furnishes an ideal location, the water being conducted by troughs or pipes into the water tank on the platform. Sometimes the water is drawn from a pond beneath the edge of the platform by means of a chain pump and delivered through a trough into the tanks and barrels. This is an excellent arrangement where the water supply is thus convenient, but lacks the desirable feature of a storage water tank.

ARSENICALS.

Several arsenical poisons are available for use, such as Paris green, Scheele's green, arsenite of lime, and arsenate of lead. These all contain arsenic and destroy insects which eat them with their food. In the work herein reported Paris green and arsenate of lead were used. A good quality of Paris green is very satisfactory, and this poison is perhaps more generally used than all other arsenicals combined. It should be used on apple at the rate of about 1 pound to 150 gallons of water or Bordeaux mixture, in which case it is simply added to the mixture, having previously been worked into a paste with water, to insure its more thorough distribution in the fungicide. Many growers use it at the rate of 1 pound to 100 gallons of spray, but there is danger of injury to apple foliage at this strength. When used alone in water the milk of lime from slaking 2 or 3 pounds of good stone lime for each 50 gallons should be added, which will neutralize any free arsenic and prevent burning. The same result is secured by the excess of lime in the Bordeaux mixture.

The arsenate of lead was purchased from the manufacturer and used at the rate of 2 pounds for each 50 gallons of Bordeaux mixture. This arsenical, as found on the market, usually occurs in the form of a thick paste, which must be entirely worked free in a small amount of water before being added to the spray tank.

Arsenate of lead has been found preferable to Paris green by some experimenters, as a much greater quantity may be used without injury to the foliage, and it adheres longer. However, when used with Bordeaux mixture Paris green is not readily washed off by rains, is apparently as satisfactory as the former, and at the strength used costs less.

Scheele's green is similar to Paris green, but contains no acetic acid. Being a finer powder, it remains in suspension longer, and costs about one-half less.

Arsenite of lime is much the cheapest of the arsenicals used in spraying, and has been found to be quite efficient. It may be prepared according to the following formula:

White arsenic	pound..	1
Sal soda (crystals).....	pounds..	4
Water.....	gallon..	1

All of the ingredients are boiled together for a few minutes, or until dissolved, and any water lost by evaporation added. This constitutes a stock solution, which will keep indefinitely, 1 pint being used with each 40 or 50 gallons of Bordeaux mixture or water. If used with water, the milk of lime from slaking 2 or 3 pounds of good stone lime must be added to produce the arsenite of lime and the

color of the spray will show how thoroughly the spraying is being done. When used in Bordeaux mixture, no additional lime will be necessary.

In the use of poisons around the home the greatest care should at all times be exercised to prevent accidents. All packages and bottles containing poison should be plainly labeled and kept locked up. Utensils used in preparing poisons for sprays should be thoroughly washed after use.

EQUIPMENT FOR SPRAYING.

With other conditions favorable, the orchardist will not be able to secure satisfactory results in spraying unless he uses an efficient spraying outfit. The outfits in use in some orchards are a practical handicap to good work. There are now on the market many different makes of spray pumps, and some of them are quite efficient and successful. The orchardist can not afford to use any but the best.

The barrel type of pump is largely used in small to medium-sized orchards, and when properly fitted with hose of sufficient length, a good agitator, and nozzles, very effective work may be done. The pump, according to its design, is fitted to the end or side of an ordinary 50-gallon kerosene or similar barrel, which is mounted on a sled, on wheels, or, better, placed in a cart or wagon. One man is required to pump, and one or two men to handle the nozzles, depending on whether one or two leads of hose are used. A good barrel pump should supply two leads of hose, each with double nozzles. Tank outfits are mostly used in the larger orchards, but are very desirable for the small orchardist as well. These consist of rectangular or half-round tanks, flat on top, holding from 100 to 300 gallons of the spray mixture, fitted to the wagon in place of the wagon bed. Some growers use a 100 to 200 gallon hogshead tank placed on one end of the wagon. The barrel type of pumps may be used on these tanks, but it is better to use the larger tank pumps made for the purpose with suction hose. The hole in the top of the tank should be covered with a close-fitting lid to keep out leaves, twigs, and other trash which would clog the pump and nozzles.

Gasoline, steam, or other power outfits are much superior to the hand-power tank or barrel pumps, and where the orchard interest warrants, a power pump should by all means be used. A much higher pressure may be maintained than is possible with hand pumps, giving a fine, mist-like spray penetrating to all parts of the tree and covering every inch of surface. Sufficient power will be furnished to supply several leads of hose, and the spraying may be done quite rapidly, which is very important, especially in regions where suitable days for spraying are infrequent.

A usual defect in spraying outfits is that the hose is not of sufficient length. Each lead of hose should be from 25 to 35 feet long (or from 50 to 75 feet where the second row on each side is to be sprayed) and provided with an 8 to 12 foot bamboo extension rod. This length of hose will permit the complete spraying of a tree before leaving it, insuring more thorough work than if but one side is sprayed at a time, and the amount of driving necessary will be reduced by one-half. (See fig. 7.) In spraying apple orchards an extension rod 10 feet in length will ordinarily be required, although shorter or longer rods are frequently used.

The nozzle is perhaps the most important part of the spraying outfit. There are many kinds of nozzles on the market, most of which

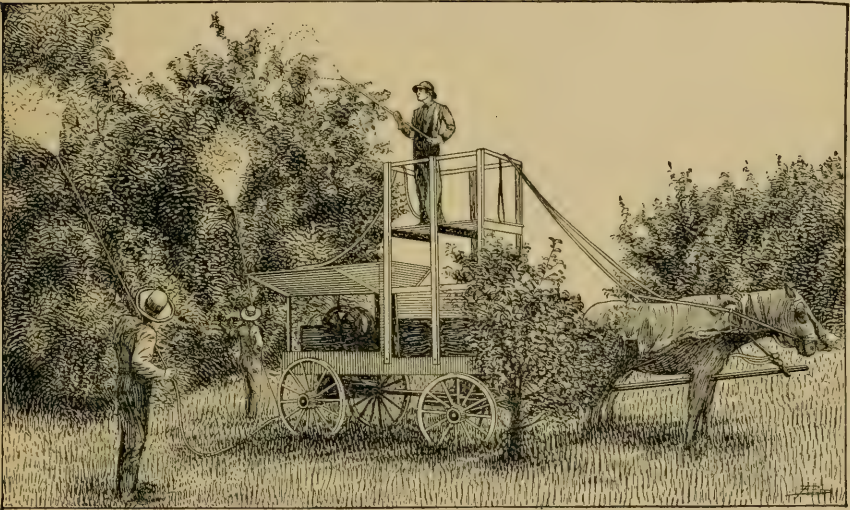


FIG. 7.—Power sprayer at work in the Gipple orchard.

are very unsatisfactory for orchard spraying. The Vermorel type of nozzle is best and should be used. The orchardist should not make the mistake of fitting an otherwise effective spray outfit with a poor nozzle. With hand-power pumps a double Vermorel nozzle for each lead of hose is satisfactory, but for power outfits triple or even quadruple nozzles may be used to good advantage. Many orchardists make the mistake of using nozzles with large apertures, thinking it desirable to discharge large quantities of the liquid. Small or medium-sized openings are required for producing a fine spray.

In spraying high trees some form of elevated platform should be constructed on the wagon, on which one of the nozzle men may stand to spray the higher parts of the trees, the other men spraying from the ground as high as may be reached.

APPLYING THE SPRAY.

Sprays are preventive and not curative, and must therefore be applied before the injury becomes apparent. After a fungus has gained entrance to the foliage or fruit, it can not be reached and the diseased parts made sound again; but the infection may be prevented by coating the parts with a fungicide, such as Bordeaux mixture, which prevents the germination of the spores. Similarly, the codling moth may not be poisoned after it has burrowed into the fruit, but if the poison has been put in the calyx cavities before the calyx lobes close and has been sprayed on the foliage and fruit before the latter is entered by the larvæ, the destruction of the latter in large numbers is insured. Successful spraying, therefore, must be based on a knowledge of the diseases and insects to be controlled. With all of the affections here considered the work should be done in advance of their expected appearance in the orchard. There are two principal reasons why spraying in the hands of some is unsatisfactory, namely, failure to make the applications at the proper time and failure to thoroughly coat the trees and fruit with the mixture. In order to overcome the former difficulty the orchardist must be informed as to the nature of the malady or insect to be treated, and the latter may be overcome by maintaining proper equipment and by giving the necessary attention to thoroughness in spraying.

In the operation of spraying the liquid should be broken into a very fine mist. The nozzles should be so manipulated that every part of the foliage and fruit shall be uniformly covered with fine dots of the spray. It is not necessary that the foliage and fruit should be actually coated with the spray, but every portion should be thickly peppered with it. The higher and inner portions of the tree are commonly insufficiently sprayed, and while the liquid may actually be dripping from the lower branches, the upper parts of the tree may show but little of the spray.

The desired mist-like spray can ordinarily be secured only with high pressure at the pump. This pressure should be not less than 100 pounds, though this is not ordinarily obtained except with gasoline or other power outfits, which should supply a pressure of 125 pounds to 150 pounds. When hand pumps are used the pressure should be maintained as high as practicable, and never less than 75 pounds, in which case good nozzles become more essential for perfect work. To maintain this pressure will require constant hard work, and the tendency will be to allow the pressure to lighten. Except in spraying the tops of trees the nozzle men should never ride in the wagon, even while spraying the smallest trees. In order to reach the inner branches and the underside of the fruit and foliage the operator

must spray from the ground, where he is free to walk around and under the trees. Many failures result from attempts to spray trees from the wagon as the outfit is being driven by.

INJURY TO FOLIAGE FROM SPRAYS.

Under certain conditions there may be in some years more or less russetting of the fruit and injury to foliage from the use of Bordeaux mixture, the injury mostly to the fruit following the applications made soon after the falling of the petals, for the apple scab. In several of the demonstration orchards in the Ozarks and in Nebraska injury to foliage and fruit was noticed. The russetting of the fruit, however, in most cases gradually disappeared as the apples developed, and at picking time was scarcely noticeable. In the Hansell orchard at Fordland a few of the apples at picking time were so russeted as to be undesirable for packing. Also some foliage injury resulted from the July and August applications of Bordeaux mixture and arsenicals, the foliage on the newer growth being in some cases scorched and browned around the edges of the leaves, and in others these became yellow, a small percentage falling. The foliage injury, however, was soon outgrown and by autumn the sprayed trees carried a heavy foliage, whereas the unsprayed trees were practically bare on account of injury from leaf-spot diseases, as already described. (See fig. 3.)

SCHEDULE OF APPLICATIONS.

The following schedule of applications is recommended as a system of orchard spraying for regions where all of the several affections herein considered are likely to occur, as in the Ozarks. The treatment for each of these troubles when considered alone has been given in connection with their discussion in the preceding pages, and where they do not all occur together the orchardist will be able to arrange a combination treatment for his particular troubles. With some varieties, practically immune to scab, the first application may be unnecessary, and the first treatment required is the second one of the schedule, i. e., for the codling moth. In localities, or with varieties immune to the bitter-rot, the last application of Bordeaux mixture may be omitted, or the amount of copper sulphate in the formula reduced.

First application.—Spray with Bordeaux mixture (5-5-50 formula) and an arsenical, after the cluster buds have opened, but prior to blooming. This is the first scab treatment, and is made to prevent that disease from infecting the fruit buds and young, unfolding leaves. The arsenical will destroy any larvæ feeding on the foliage or buds, such as canker worms, bud-moth, etc.

Second application.—Spray with Bordeaux mixture and an arsenical, as 2 pounds of arsenate of lead or 6 ounces of Paris green to 50 gallons of the Bordeaux mixture, immediately after the petals fall. This is the second treatment for scab and the first for the codling moth. Special pains must be taken to fill with the spray the calyx cavity of each little apple, where the poison will be retained to kill the young larvæ as they attempt later to enter the fruit. If this application has not been thoroughly made, a supplemental treatment should be given within a week and before the calyx lobes close, in order to further insure the poisoning of each calyx cavity and afford additional protection against the scab.

Third application.—Spray with Bordeaux mixture and an arsenical, as above, three weeks from the dropping of the petals. This treatment is especially important for destroying codling moth larvæ just as they are hatching from eggs placed here and there on the foliage and fruit. It is also an important treatment in the control of leaf-spot diseases, and in some seasons is necessary for the prevention of scab.

Fourth application.—Spray with Bordeaux mixture and an arsenical, as above, six or seven weeks after the petals fall. This is the first treatment for the bitter-rot and apple blotch diseases, and is also important for the control of leaf-spot. Where the preceding applications have been omitted and the weather conditions (hot and showery) indicate an early infection period, this treatment should perhaps be made a week earlier.

Fifth application.—Spray with Bordeaux mixture and an arsenical, as above, about nine weeks from the close of the blooming period or two weeks later than the fourth application. This constitutes the second application for the bitter-rot and apple blotch diseases, and the first for the second brood of the codling moth. It also affords further protection against leaf-spot.

Sixth application.—Spray with Bordeaux mixture and an arsenical, as above, about twelve weeks after the petals fall or three weeks after the fifth application. This constitutes the second application for the second brood of the codling moth and the third for the bitter-rot and apple blotch diseases.

FARMERS' BULLETINS.

The following is a list of the Farmers' Bulletins available for distribution, showing the number, title, and size in pages of each. Copies will be sent free to any address in the United States on application to a Senator, Representative, or Delegate in Congress, or to the Secretary of Agriculture, Washington, D. C. Numbers omitted have been discontinued, being superseded by later bulletins.

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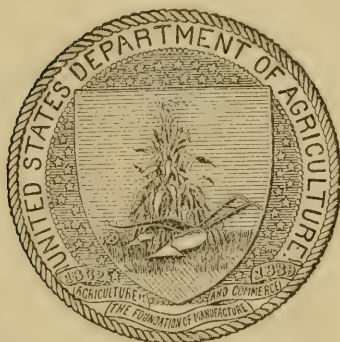
INSECT AND FUNGOUS ENEMIES OF
THE GRAPE EAST OF THE
ROCKY MOUNTAINS.

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
Washington, D. C., March 6, 1907.

SIR: We have the honor to transmit herewith a paper entitled "Insect and Fungous Enemies of the Grape East of the Rocky Mountains," prepared by Mr. A. L. Quaintance, of the Bureau of Entomology, and Dr. C. L. Shear, of the Bureau of Plant Industry.

This bulletin treats of the principal insect and fungous enemies of the American varieties of grapes, giving the most successful methods of treatment at present known. It first states the nature of the insect enemies and the means of controlling them, then discusses the fungous parasites, including treatment, and in conclusion gives an account of spraying apparatus, with directions for applying spray mixtures. The reason for the joint publication arises from the fact that the remedial measures used in combating the insects and the fungous parasites are of such a nature that the applications can be combined and thereby result in a great reduction in cost of time and labor. We recommend the publication of this paper as a Farmers' Bulletin.

Respectfully,

L. O. HOWARD,
Chief of the Bureau of Entomology.

B. T. GALLOWAY,
Chief of the Bureau of Plant Industry.

HON. JAMES WILSON,
Secretary of Agriculture.

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INSECT AND FUNGOUS ENEMIES OF THE GRAPE EAST OF THE ROCKY MOUNTAINS.

INSECT ENEMIES.

All of the important insect enemies of the grape in the United States at the present time are native American species, feeding originally, as they do at the present day, on various wild species of grapes and related plants. With the planting of vineyards and the extension of the grape-growing industry many species attacked also the cultivated varieties, and some few have become exceedingly troublesome pests. Perhaps no horticultural crop so well illustrates the serious loss which may result from native species of insects attacking cultivated varieties of their natural wild food plants as does the grape. As a rule, varieties with a preponderance in parentage of the European grape (*Vitis vinifera*) are not vigorous growers in the Middle and Eastern States and suffer to a greater degree from insect attack than varieties with parentage of American vines. But these latter are not exempt and, with the exception of one or two insects, are equally subject to attack. The principal exception to be noted is the grape phylloxera, an aphide or "plant louse" which infests the roots and also the leaves of the grape and is especially injurious to vinifera or European varieties. Several species of American grapes and some of their hybrids and varieties, and other kinds to a less degree, are resistant to attack from this insect, and these are used as grafting stock for vinifera varieties in California and Europe, where the insect has been and is especially troublesome. It has been suggested that certain species or varieties of American grapes are resistant to the grape root-worm also, and although there is no evidence bearing on the question, the matter is of sufficient importance to warrant careful investigation.

Of the two hundred or more species of insects known to feed upon the grape in the United States, those treated herein include, with the exception of the phylloxera, those of principal importance, namely, the grape root-worm, grape berry moth, grape curculio, grape leaf-hopper, grape leaf-folder, grapevine flea-beetle, and rose-chafer. Grape insects are not less amenable to treatment than insect pests of other fruit crops, and the vineyardist may confidently expect to be

able to keep them under control by the application of the remedies herein recommended. As the reader will learn in the following pages, the principal insect and fungous enemies of the grape may be controlled with material reduction of cost by timely and thorough applications of a combined insecticide and fungicide used in the form of a liquid spray. As in the control of most other insect pests, cultural methods are of very great importance. Vines kept in a vigorous, healthy condition by cultivations and fertilization are much better able to withstand insect attack than those grown under conditions of neglect.

THE GRAPE ROOT-WORM.

The grape root-worm (*Fidia viticida* Walsh), as the name indicates infests the roots of the grape, devouring more or less completely the smaller roots and rootlets and eating pits or burrows into the outer portion of the larger roots. It is the larva of a small, hairy, chestnut-brown beetle which makes its appearance in vineyards at about the close of the blooming period of such varieties of grapes as Concord, Niagara, Catawba, and Delaware. The beetles feed freely on the upper surface of the leaf, eating a series of patches or holes through to the lower surface, thus producing characteristic chain-like feeding marks, as shown in figure 1 at *h*, by which their presence in vineyards may be readily detected. The injury to the foliage, however, is quite unimportant compared to the work of the larvæ on the roots. When the larvæ are abundant the vines may be killed in the course of a season or two, but usually the plants will live longer, though making but a feeble growth and failing to produce profitable crops. The death of vines or the gradual failure of a vineyard should call for an examination of the foliage for the feeding marks of the beetles and of the roots for the work of the larvæ on these parts.

Distribution and Destructiveness.

The grape root-worm, or grapevine *Fidia*, is without doubt a native species, feeding originally on wild grapes, as it does at the present time. In addition to cultivated varieties of grapes it has also been recorded as feeding on the Virginia creeper (*Ampelopsis quinquefolia*) and the American red-bud (*Cercis canadensis*). In the literature of the species it is said to occur in Iowa, Missouri, Arkansas, Illinois, Kentucky, Ohio, New York, and New Jersey. In 1892 Doctor Horn gave the distribution of the insect as from the "Middle States to Dakota, Florida, and Texas." According to the records of the Bureau of Entomology the insect occurs in New York, Pennsylvania, Virginia, North Carolina, Ohio, Illinois, Kentucky, Missouri, Mississippi, Texas, and California. The species is therefore widely distributed in the Mississippi Valley and in the Eastern States, and occurs also in California.

This insect first came into notice as a pest of cultivated grapes in 1866, in Kentucky, by reason of injury to the foliage caused by the adults or beetles. This attack was the subject of a short note by Mr. B. D. Walsh in the *Practical Entomologist*.^a The following

^a *Practical Entomologist*, Vol. 1, p. 99 (1866).

year the species was described by Mr. Walsh and given the name it still bears.^a Riley in 1879, in his First Report on the Injurious Insects of Missouri, regarded the insect as one of the worst pests of the vine in that State, where it occurred abundantly and was mis-called the rose bug (*Macrodactylus subspinosus*). In 1893 and subsequently the insect became very injurious in vineyards in northern Ohio, and was carefully investigated by Prof. F. M. Webster,^b who showed that the larvæ or grubs of the beetle fed upon the roots of the vine, causing much more serious damage than was caused by the beetles in feeding upon the foliage. In 1900 the insect was discovered by Professor Slingerland^c to occur in injurious numbers in vineyards in the Chautauqua grape belt in western New York, and during the three or four years following was carefully studied by him and also by Dr. E. P. Felt, and effective remedial measures were devised by extensive practical experiments. At the present time the grape root-worm continues to be a pest of importance in the vineyards of northern Ohio, the Erie grape belt in Pennsylvania, and the Chautauqua region of western New York. Throughout these regions the insect on the whole seems to be diminishing in importance, in part through natural agencies but more especially following adequate cultivation of vineyards and the use of sprays.

The insect thrives best in vineyards which are neglected; in the absence of cultivation and timely spraying it is likely to become a serious pest in any vineyard throughout its range of distribution. This is especially the case in light, sandy soils and in regions where grape growing is a considerable industry.

Description and Life History.

Adult.—The beetle, or parent insect of the grape root-worm, is shown enlarged at *a*, figure 1. It is about one-fourth of an inch long, rather stout, with long legs, the body brownish in color and covered with grayish white hairs. The adults make their appearance in vineyards beginning about the close of the blooming period of the vines, which in the New York, Pennsylvania, and Ohio grape districts, during normal seasons, will be from about the 15th to about the 20th of June. The great majority of beetles will appear during the latter part of June and the first two or three weeks of July, though a few will be coming out during the latter part of July, and stragglers may appear for a month or six weeks later. In a given locality there will be some variation in the time of appearance, which will be earlier on light, sandy soils or warmer locations and later on heavier soils. In the course of a few days after emergence the beetles begin to feed, eating rows of holes in the upper surface of the leaf, as shown in figure 1 at *h*. After some days of feeding the females begin to deposit eggs, the number for an individual female varying considerably. Doctor Felt^d has obtained egg-laying records of 156, 342, and 902 eggs, respectively, for three individuals, and the averages per insect from three lots of insects kept under observation were 141, 192, and 488, respectively, the average for the

^a Practical Entomologist, Vol. 2, pp. 87–88 (1867).

^b Bul. 62, Ohio Agrl. Exp. Station (1895).

^c Bul. 184, Cornell Univ. Agrl. Exp. Station (1900).

^d Bul. 19, Office State Ent. of N. Y., p. 20 (1903).

entire number being nearly 175 eggs per female. According to the same writer, about 45 per cent of the eggs of the individuals above mentioned were deposited during the first two weeks, and 73 per cent of the entire number were deposited during the first month after emergence. Beetles are to be found on the vines during a considerable period, owing to their longevity and to an irregularity in emergence, though, as stated, oviposition is largely done during the three or four weeks fol-

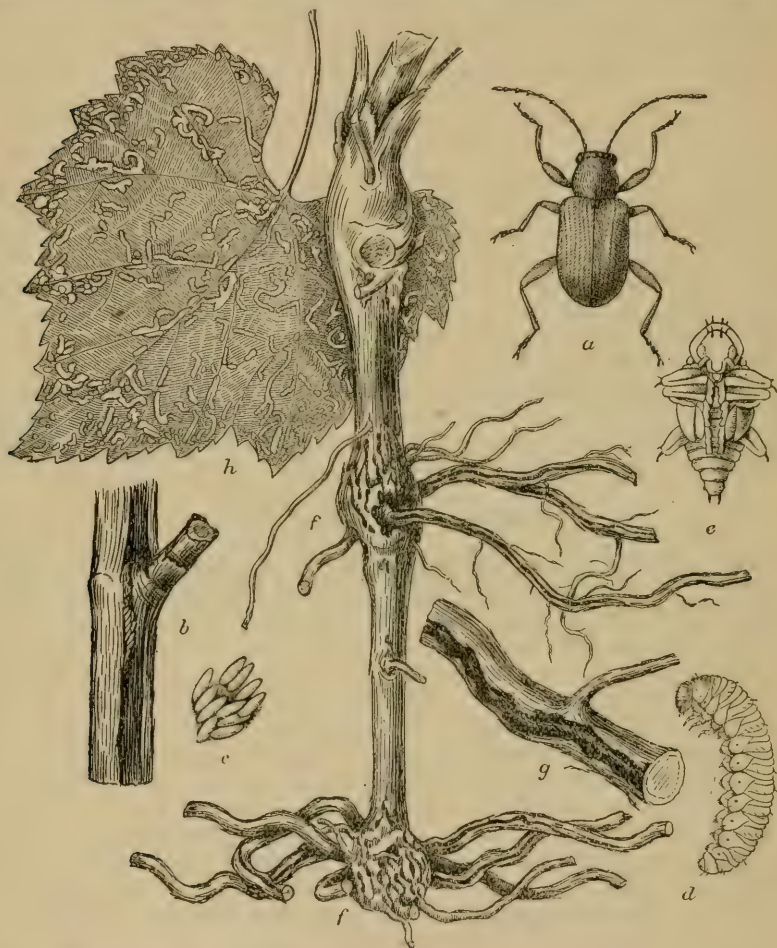


FIG. 1.—Grape root-worm (*Fidia viticida*): a, Adult or beetle; b, eggs on cane, about natural size; c, eggs, enlarged; d, full-grown larva; e, pupa; f, f, g, roots of grape, showing injury by larvæ; h, grape leaf, showing characteristic chain-like feeding marks made by beetles. a, c, d, e, Much enlarged; b, g, about natural size; f, h, reduced.

lowing emergence. Upon being disturbed many of the beetles will lose their hold upon the vines and fall to the ground in their efforts to escape detection. Advantage may be taken of this fact, as explained later, to collect the insects from the vines by jarring.

Egg.—Eggs are deposited in patches usually from 25 to 40, sometimes less, but rarely more, according to Slingerland, mostly under the

bark of last year's wood, and may occur quite generally over the canes, some quite near to the upper wire of the trellis. As stated by Professor Webster^a, 700 eggs were found on a single vine, and 225 eggs from a section of a cane but 16 inches long. The eggs are nearly cylindrical in shape, tapering at each end; whitish when first laid, but soon becoming yellowish in color. The eggs are about one-twenty-fifth of an inch in length, and more or less concentrically arranged in patches. From 9 to 12 days are required for the eggs to hatch. See figure 1, at *b* and *c*, showing eggs on grape cane and more enlarged.

Larva.—On hatching, the larvæ drop to the ground. At this time they are about one-seventeenth of an inch in length, and from their small size are readily able to find their way through the soil. Although the powers of locomotion and endurance of the young larvæ are considerable, to enable them to overcome difficulties in reaching their food, many doubtless fail to do so and perish. When established on the roots, however, the grubs feed freely and grow rapidly. By fall the majority of them will be full-grown or nearly so. Upon the approach of cold weather they descend into the earth several inches, a few as much as a foot below the surface, and here construct oval earthen cells in which they pass the winter. With the approach of warm weather the larvæ ascend to a point near the surface, the immature ones completing their growth, and the pupal stage is entered mostly from about 2 to 3 inches below the surface of the soil and within a radius of 1½ to 2 feet from the base of the vine. The full-grown larva is about five-eighths of an inch long, the body whitish, resting in a curved position. The head is yellowish brown in color, with a transverse diameter somewhat less than that of the body. The spiracles or breathing pores along each side are well marked, varying from light to yellowish brown in color. As shown in figure 1, at *d*, the insect in this stage resembles in miniature one of the common white grubs, from which it may be distinguished by the dark food material in the abdomen of the latter.

Pupa.—The full-grown larva prepares an earthen cell, within which it shortly changes to the pupa or "turtle" stage. In this condition the insect is soft and helpless, and the earthen cells are readily broken open and the pupæ crushed or otherwise killed by stirring the soil. As stated, the majority of the larvæ pupate about 2 or 3 inches below the surface of the ground, and this makes possible their destruction in large numbers by timely cultivations, as will be explained under the discussion of remedies. Pupation is perhaps at its height just before the blossoms of the grape begin to open, but the vineyardist may determine the period with exactness by examining the earth around the base of infested vines to ascertain the proportion of pupæ and larvæ present. Throughout the Chautauqua, Erie, and Ohio grape belts, during normal seasons, the insects will be in the pupal stage in maximum numbers during the first two or three weeks of June, varying somewhat, however, according to season and the character of the soil, being earlier on sandy and later on clay soils. The pupa is shown in figure 1 at *e*. It is from one-fourth to one-third of an inch long, whitish in color, but with a pinkish coloration about the head, thorax, and caudal portion. On the head, body, and appendages are spines, as shown in the figure. The pupal stage lasts about two weeks.

^a Bul. 62, Ohio Agrl. Exp. Station, p. 82 (1895).

Natural Enemies.

No parasitic enemies of the beetles, pupæ, or larvæ are recorded, but Professor Webster, in Ohio, has bred from the eggs two species of small hymenopterous wasps, namely, *Fidiobia flavipes* Ashm., and *Brachysticha fidie* Ashm., which he found to be doing most excellent work. The former parasite was also bred from eggs by Slingerland in New York State in 1905. Eggs are also attacked by two or three species of small mites, which destroy them by extracting the contents. The common little brown ant, *Lasius brunneus* var. *alienus*, also has been observed to feed upon the eggs, and several predaceous insects were found by Dr. E. P. Felt in the course of his field work in New York occurring in the soil infested by root-worms, and he thought it probable that these preyed upon this species. The beetles are no doubt fed upon by insectivorous birds and barnyard fowls, which also are known to feed upon the pupæ exposed in cultivating.

Treatment.

The insect may be fought in three important ways, namely, by poisoning the adults with an arsenical spray, jarring them from the vines onto sheets, and destroying the pupæ in the soil by cultivation.

Poisoning.—Shortly after emergence the beetles begin to feed upon the foliage, eating holes in the upper surface of the grape leaves, and hence may be readily poisoned. The use of poisons was recommended by Mr. Marlatt^a in 1895, while Messrs. Slingerland and Johnson have shown by extensive practical experiments that the numbers of the pest may be greatly reduced in this way, and that poisoning in conjunction with cultivation, to be later mentioned, affords almost complete protection from its injuries. To be effective, however, the poisoned spray must be applied at the right times and with great thoroughness. The beetles begin to put in an appearance at about the close of the blooming period. Careful watch should be kept, and upon the first signs of the chain-like feeding marks on the leaves the vines should be thoroughly sprayed with a poison. A second application should be made in a week or ten days. These applications are intended to poison the newly emerged beetles during their first feeding and before they have deposited their eggs to any extent. If applications be delayed two or three weeks beyond the time indicated, a considerable percentage of the eggs will have been deposited, and the treatments will lose much of their value. Vineyardists having this pest to contend with should not make the mistake of spraying a little too late, but should have everything in readiness to begin applications upon the first appearance of the beetles. The beetles plainly avoid feeding on foliage sprayed with Bordeaux mixture or arsenate of lead, seeking the unsprayed leaves as much as possible. It is therefore especially necessary to make applications with great thoroughness, poisoning as nearly as possible the upper surface of every leaf, so that the beetles will be poisoned or forced to leave the vines for food. This desired thoroughness of treatment is not obtained as a rule by vineyardists, and greater care should be exercised in this work. In commercial vineyards the tendency will be to hurry through the

^a Yearbook U. S. Dept. of Agriculture, 1895, p. 393.

work, covering 12 or 15 acres per day, using an insufficient amount of spray. With the spraying machinery in common use 7 to 8 acres per day is about all that may be covered with the desired thoroughness, and about 125 gallons of spray mixture should be applied per acre. In spraying for the grape root-worm, the poison should always be applied in Bordeaux mixture, which is used in the control of fungous diseases, as elsewhere considered in this bulletin. The several arsenical poisons which may be used are discussed on pages 26 and 27.

Destruction of beetles by jarring.—Doctor Felt has made extensive practical tests of jarring the beetles from the vines and catching them on sheets or special forms of catchers run under the plants or along the rows, and considers this to be an effective plan of controlling the pest, the jarring of the vines causing many of the beetles to fall in their efforts to escape detection. A sheet of canvas placed on the ground beneath the vines will serve to catch the beetles, but where work of this kind is done on a large scale special apparatus must be provided. There is room for considerable ingenuity in constructing catchers that will suit individual conditions. Concerning the value of jarring, Doctor Felt says:^a "Our experience with collectors has demonstrated the practicability of catching the beetles, and we recommend this operation for all badly infested sections, and that the collecting be begun as soon as the beetles appear on the vines in any numbers, say where there are 12 or 15 on one. The operation should then be repeated at intervals of 5 to 7 days till the vines have been gone over two, three, or four times, depending somewhat on the number of insects which are captured. It will be found that it is much easier to catch the beetles on warm days, when it should be done, than in cool weather."

Destruction of pupæ by cultivation.—While the grape root-worm may be present in well cultivated vineyards, it is much less destructive than in vineyards which receive indifferent cultivation or total neglect. It has long been known that much good may be done in controlling insects which live underground by breaking open their pupal cells and crushing or otherwise killing the helpless pupæ. The importance of this work in the destruction of pupæ of the grape root-worm was first pointed out by Professor Slingerland in his studies of this pest in the Chautauqua grape belt, and subsequent experiments, confirmed by practical experience, have shown that this is a very important method of reducing the numbers of insects. After the larvæ have become full grown the great majority pupate but 2 or 3 inches below the surface of the soil, and mostly within a radius of 1½ or 2 feet from the base of the vine. In this stage the insects are quite helpless, and are killed in large numbers by a thorough breaking up of the soil around the base of the plants. As stated, the insect will be in the pupal stage in maximum numbers just before the period of blooming of the vines, and the cultivating should be done at this time. In the Ohio, Pennsylvania, and New York grape districts this will be about the middle of June, the time varying somewhat according to the character of the season and of the soil. The details of this work are very important and require explanation.

With the last cultivation in the fall the earth should be thrown to the vines on each side, forming a ridge along the row. The following

^a Bul. 19, Office State Ent. of N. Y., p. 37 (1903).

spring the larvæ in making their way toward the surface of the soil to pupate will mostly work up in this ridge of earth, above the surface of the roots, and there enter the pupal stage. The cultivation of the vineyard in the spring should be so adjusted that this ridge of earth may be thrown away from the vines when most of the insects are in the pupal stage, as one of the regular cultivations. An implement known as a "horse-hoe," generally used in vineyards, may be employed to great advantage in this work; but as it is not practicable to remove the earth from immediately around the vine owing to danger of injury, it is necessary to follow the horse-hoe at once and remove the earth with a hand-hoe. The latter work is also done as a part of the regular vineyard treatment to keep down weeds and grass, and is timed so as to supplement the plowing with the horse-hoe for the insect. Following the removal of the ridge of earth from along the vines, it is well to keep the ground stirred at frequent intervals by means of a cultivator to further insure the destruction of the pupæ.

GRAPE BERRY MOTH.

The larva of the grape berry moth (*Polychrosis viteana* Clem.) infests the berry or fruit of the grape. The first generation attacks and webs together the grape clusters even before the blossoms open or soon after the grapes are set. Later-appearing larvæ bore into the green or ripening fruit and produce a purplish spot much resembling in appearance the injury due to the black-rot fungus, with which it is frequently confused. Within the fruit the larvæ feed on the pulp and seeds, passing from one grape to another, and several of these discolored and shriveling berries will often be found more or less webbed together with numerous particles of larval excrement, and sticky with exuding grape juice. Other insects attack the fruit of the grape, such as the grape-seed insect (*Isosoma vitis* Saunders), whose larvæ feed on the seeds, causing the berries to shrivel late in the summer, and the grape curculio (*Craponius inæqualis* Say), whose injury closely resembles that of the grape berry moth and is considered on a later page. But the principal cause of wormy grapes throughout the country is the larva of the species under consideration. Until recently it was thought that our grape berry moth was introduced from Europe many years ago. But Messrs. Slingerland and Kearfott have shown,^a by careful study of this insect and related species, that the insect infesting American vineyards is quite distinct from the European form (*Polychrosis botrana* Schiff). These gentlemen have also shown that the American grape berry moth does not feed upon sumac, as was formerly held, and consider it very probable that the grape is the sole food of this species. This important fact greatly simplifies the question of its control, for if the species had other food plants vineyards would be reinfested from outside sources despite thorough treatments.

Distribution and Destructiveness.

The American grape berry moth occurs from Canada south to the Gulf and westward to California. It is very generally distributed over this area, and wherever the grape is grown it is more than likely to be

^a Bul. 223, Cornell Univ. Agrl. Exp. Sta. (1904).

found. For a number of years the pest has been troublesome in Ohio vineyards, and also more or less locally in the Erie grape belt and in New York State. In 1902, according to Slingerland, it was destructive all through the Chautauqua grape belt, and was equally destructive through a large part of this area during the two succeeding years. At the present time the insect is destructive in individual vineyards here and there throughout the Chautauqua, Erie, and northern Ohio grape districts, causing a loss of many thousands of dollars annually. In some vineyards a loss of from 25 to 50 per cent of the crop is not infrequent, and in occasional instances the destruction of the fruit is practically complete.

Description and Life History.

The grape berry moth is small, the wings expanding not quite one-half inch. The general color is purplish brown, the wings with markings as shown in figure 2. Moths appear in the spring from hibernating pupæ, beginning about the time the shoots of the grape are pushing out, and continuing to emerge for some weeks. The earlier-appearing individuals deposit their eggs on the blossom clusters, while those coming out after the blossoms are shed oviposit on the clusters of young grapes.

The minute scalelike eggs of the first brood of moths are difficult to find, as at this time they are relatively scarce, but may be readily detected during summer as a glistening or whitish spot on the surface of the berries. The larvæ of the first generation feed upon the blossoms and small berries, webbing them together more or less and producing a more or less ragged bunch of grapes, or the cluster may be almost entirely destroyed. The capabilities of the larvæ for injury at this time are thus seen to be much greater than is the case with larvæ of the later broods, by which individual berries are attacked. The spring brood, however, is usually quite small; evidently there is a heavy mortality of the insect during the preceding fall and winter. About 3 weeks are required for a larva to complete its growth in summer, when it is about three-eighths of an inch in length, slender, light greenish to purplish in color, the head slightly bilobed, greenish above, and brownish in front, the thoracic feet blackish. When ready to pupate the larvæ go to the leaves, and a small portion is cut loose, except along one side, and bent over and fastened down with silk. Beneath this a thin, whitish, silken cocoon is spun, and in 3 to 4 days the larva changes to a light greenish brown pupa, from which the moth will emerge in some 12 to 14 days. The larva and curious cocoon and pupa are shown in figure 2, considerably enlarged. Moths of the second and later generations deposit their eggs on the developing grape berries, and the resulting larvæ bore into these, feeding on the pulp and seeds, the entrance point of the berry being marked by a purplish spot, which renders their detection quite easy. In the Chautauqua and Erie grape belts, and probably in northern Ohio, moths of the second generation will begin coming out and ovipositing about the first week or ten days of July, continuing for some weeks, the first and second broods overlapping. By this time the insects will have increased greatly in numbers, and the larvæ will be attacking almost exclusively the berries of the grape,

for which reason their work is much more conspicuous. Second-brood larvæ infest the grape during July and August, the later-appearing individuals probably not developing to moths but hibernating in the pupal condition. Many of the earlier-appearing insects of this brood appear to complete their life cycle, and moths develop, giving rise to a third generation of larvæ. According to the observations of Mr. Fred Johnson, of the Bureau of Entomology, at North East, Pa., practically a full third brood was produced during 1906. On September 7, according to this observer, larvæ one-third to one-half grown were very numerous, from 80 to 90 per cent of the berries in many clusters having been injured. Egg shells were very abundant on the fruit, which at this time was beginning to color. Many of the eggs had been parasitized by what is probably *Trichogramma pretiosa* Riley, a minute hymenopterous fly which oviposits in the eggs of many species of lepidopterous insects. A few larvæ were found in berries by Mr. Johnson as late as October 17, though practically all of the larvæ had left the fruit. They were found mostly on the leaves, which had already fallen to the ground, where

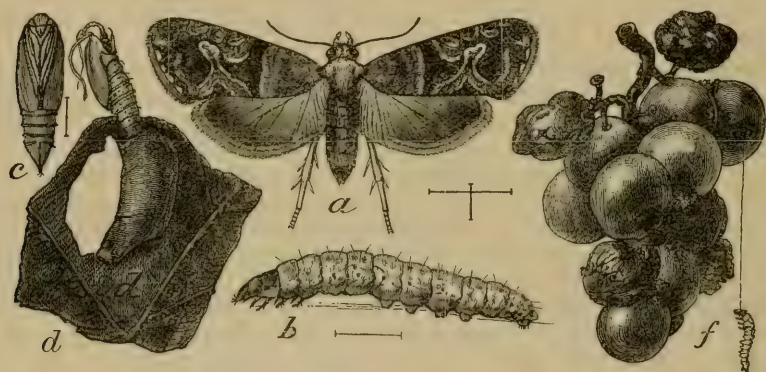


FIG. 2.—Grape berry moth (*Polychrosis viteana*): a, Adult or moth; b, larva; c, pupa; d, folded leaf, with pupa shell projecting from case cut from the leaf; e, pupa shell; f, grapes, showing injury, and larva suspended by its silk. All much enlarged, except f, somewhat reduced. (From Marlatt.)

it appeared the larvæ went to pupate, scarcely any being found on the foliage still attached to the vines. In the Middle and Southern States it is inferred that there may be each year three full broods, or perhaps more, but as yet the insect has not been studied in this territory.

Treatment.

Poisons.—The use of arsenical poisons against the first brood of the grape berry moth was recommended by Mr. Marlatt, of the Bureau of Entomology, in 1895.^a Since this time the recommendation has been amply justified in the experience of numerous vineyardists, who, in connection with the fight against the grape root-worm, found that their early sprayings for this pest were also controlling the grape berry moth. Professor Slingerland reports an instance in which three timely applications of arsenate of lead, at the

^a Yearbook, U. S. Dept. of Agriculture, 1895, p. 404.

rate of 10 or 12 pounds to 100 gallons of water, gave almost absolute protection during the rest of the season. Doctor Felt records^a that the application of arsenate of lead along with Bordeaux mixture, for the grape root-worm, shortly after the blossoms had fallen and before the berries had grown to the size of a pea, resulted in a decrease of 50 per cent in the injury to fruit by the berry moth.

While definite experiments with poisons in the control of this pest appear not yet to have been reported,^b the experience above given indicates their great usefulness. As would appear from the life history of the insect, most effective work may be done by destroying the first brood larvæ, which feed in the clusters of blossoms and berries. The first treatment should be made just before the blossoms are ready to open, and the second just after the blossoms have fallen. A third treatment in a week or ten days is also advisable in badly infested vineyards. In all these treatments special care should be exercised to force the spray well through the clusters of blossoms and young fruit. It will be noted that the second and third treatments for the grape berry moth will coincide with the first and second treatments for the grape root-worm, and the arsenicals recommended for that insect will be equally satisfactory for the grape berry moth. (See page 10.)

Picking infested berries.—This practice is often followed by vineyardists, and is especially directed against larvæ of the second brood. The infested spotted green berries, which are readily seen, should be carefully searched for and destroyed. This practice will lessen injury from a possible later brood, and if carefully followed would reduce the insects materially in the vineyard from year to year.

Bagging clusters.—Inclosing each cluster of grapes in a paper bag soon after the blossoms have fallen should protect them from injury from second and third-brood larvæ, and would also afford protection from the rose-chafer and from black-rot. This practice is especially useful in the small home vineyard.

Gathering fallen leaves.—The fact that the insect passes the winter in fallen leaves has led to the recommendation that these be raked up and burned. From Mr. Johnson's observations it would appear important to collect these early in the fall, as the pupæ are to be found mostly on the 10 or 15 per cent of leaves which fall first, and great care must be taken to collect those leaves more or less imbedded in the soil. After remaining on the ground for a while, probably many of the cocoons break off from the leaves and would thus not be collected with the leaves. It is probable also that many of the insects could be destroyed by covering the leaves with soil early in the fall.

^a Bul. 19, Office State Ent. of N. Y., p. 31 (1903).

^b Since this article was written, definite experiments in spraying for the grape berry moth have been reported by Profs. H. A. Gossard and J. S. Houser in Circular 63 of the Ohio Agricultural Experiment Station. These gentlemen have shown that the insect may be largely controlled by three applications of an arsenical, with the addition of some form of soap to make the spray more adhesive, the time of making applications being practically as recommended above.

GRAPE CURCULIO.

The grape curculio (*Craponius inæqualis* Say) is one of the "snout beetles" belonging in the same family (Curculionidæ) as the so-called plum curculio. The parent beetle deposits her eggs in little cavities which she eats into the grapes, and the resulting larvæ feed upon the pulp and seeds, producing an injury quite similar to that done by the grape berry moth. The beetles cut small, rather characteristic holes in the grape leaves when feeding, and the berries often show a purplish coloration at the point punctured in egg-laying, as shown in figure 3. If infested berries be examined it will be readily

possible to distinguish between the grape curculio and the grape berry moth, since the grubs of the former are whitish and quite destitute of legs, whereas the larvæ of the berry moth have well-developed legs, are greenish in color, quite agile, and likely to escape quickly upon being disturbed. See figure 4, showing, at *a*, an injured berry; *c*, the egg-cavity and egg beneath skin of grape; and *d*, an infested berry cut open.

Distribution and Destructiveness.

The grape curculio is a native species, feeding originally on the wild grape, as it does at the present time. It has been recorded from Ar-

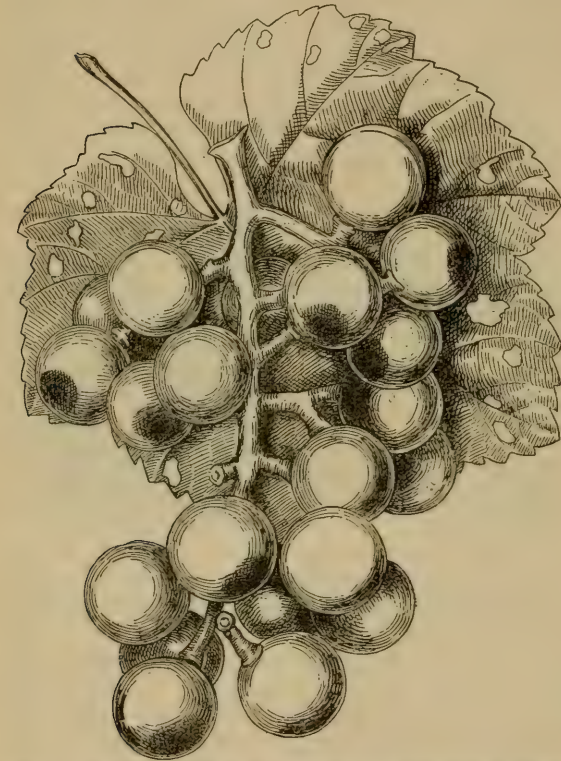


FIG. 3.—Grape leaf, showing feeding marks of grape curculio beetles, and bunch of grapes infested with larvæ. Somewhat reduced.

kansas, Missouri, Tennessee, Kentucky, Illinois, Minnesota, Ohio, New Jersey, West Virginia, and North Carolina, and, according to Lintner, it probably occurs in New York State. The Bureau of Entomology has records of its occurrence in Pennsylvania, District of Columbia, West Virginia, North Carolina, and Nebraska. According to Le Conte and Horn, its distribution is "Middle, Southern, and Western States." The insect was described in 1830 by Thomas Say, but it first attracted attention as a grape pest in 1853 in the vicinity of Cincinnati, Ohio. An account of the species was given in 1867 by

B. D. Walsh, and comments were given on its injuries in Illinois, Ohio, and Kentucky. Injury by this species is more or less local and intermittent. Serious injury was reported by G. R. Wood in 1890 in the vicinity of Sandusky, and in 1891 Professor Webster found it very destructive in vineyards in Franklin County, Ark. For the past eight or ten years the grape curculio has been very destructive in many localities in West Virginia, destroying in many vineyards a large percentage of the crop. The species has been carefully studied by Mr. Fred E. Brooks, of the West Virginia Agricultural Experiment Station, and reported on in detail in Bulletin 100 of that institution. As shown by the experience in West Virginia and elsewhere, the species, under certain conditions, may become a very serious pest, ranking with the root-worm or berry moth. Mr. Brooks has shown that the insect is readily controlled with arsenical poisons and, as will be detailed later, (p. 47) treatments for the root-worm and berry moth will also keep this pest under control.

Life History and Habits.

The insect passes the winter in the adult or beetle stage, hiding under trash in and near vineyards, especially bordering woods. About the time in the spring that the grape is in bloom the beetles come from their hibernation quarters and for the first few days or a week are quite sluggish, but gradually become more active, feeding on the foliage of the grape until the berries are about one-fourth grown or of sufficient size to be suitable for receiving the eggs—according to Mr.

Brooks, in 1905, covering a period of about 25 days. This habit of feeding on the exposed portions of the vines some 3 to 4 weeks before egg-laying permits of their ready destruction by arsenical poisons. Late in June, in the latitude of West Virginia, the females begin depositing eggs in the berries, excavating a cavity in which a single egg is placed. About 4 to 6 days, varying with the temperature, are required for the eggs to hatch, and the resulting larva burrows through the pulp, reaching the seed in 3 or 4 days, which is penetrated and the contents devoured. In 12 to 15 days the larva has become full grown and leaves the berry by eating a hole to the outside, falls to the ground and at once seeks a suitable place for pupation, as under stones, lumps of earth, or just below the surface of the soil. Here an earthen cell is made and the larva transforms to the pupa, the

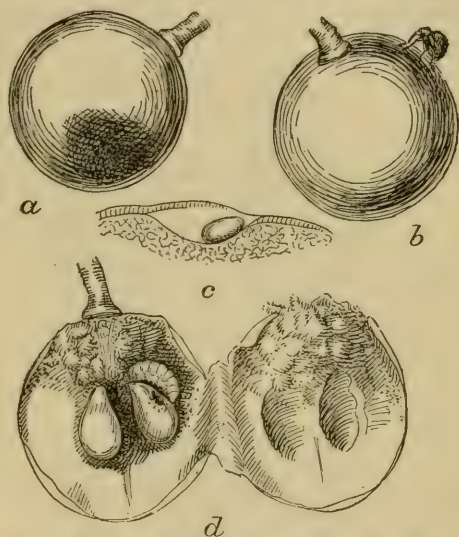


FIG. 4.—Work of grape curculio (*Craponius inaequalis*) in berry of grape: *a*, Berry from which grub or larva has emerged; *b*, adult or weevil ovipositing on berry; *c*, enlarged section of portion of berry, showing egg cavity and egg; *d*, injured berry, cut open and showing larva at work. *a*, *b*, *d*, Enlarged; *c*, highly magnified.

adult beetle emerging in the course of 18 or 19 days, at first blackish in color with gray hairs, but soon becoming the normal brown color. In figure 5 the parent beetle is shown in dorsal view at *a*, and a side view at *c*; the larva or grub is shown in dorsal and ventral views at *d* and *e*, and the pupa at *f*.

The life cycle from egg to adult, as stated by Brooks for a large series of individuals, requires about 35 days. The new generation of beetles feed upon the foliage until fall, when they go into hibernation, appearing the following spring, as stated. Mr. Brooks determined the egg-laying capacity of 30 beetles, the minimum number deposited by one insect being 63, and the maximum 392, with an average of about 257, the oviposition period extending from June 22 to September 10, a period of 81 days. Oviposition is apparently most active during the first one or two weeks of July. The beetles of the hibernating and of the new generation overlap, and the earlier-

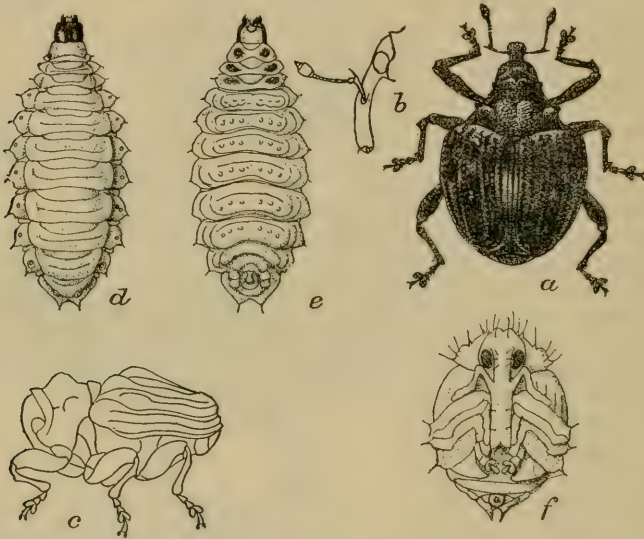


FIG. 5.—Grape curculio (*Craponus inxqualis*): *a*, Adult or beetle, from above; *b*, head, antenna, and beak of same, from side; *c*, adult, from side; *d*, larva, from above; *e*, same, from below; *f*, pupa, from below. All much enlarged.

appearing individuals of the latter may oviposit, but the resulting larvæ will mostly fail to reach maturity. Practically there is but one generation a year in the latitude of West Virginia, while in the South a second generation may occur, though it is considered doubtful.

Treatment.

Poisoning.—The beetles feed freely upon the foliage of the grape in the spring for several weeks before egg-laying begins and continue feeding in the fall after egg-laying ceases along with beetles of the new generation, and it is thus an easy matter to bring about their destruction by arsenical sprays. The treatments advised for the grape berry moth and root-worm, with perhaps an additional treatment 2 or 3 weeks later, will practically control the insect.

Bagging.—Fruit may also be well protected by bagging the clusters soon after the grapes have set, as already mentioned in connection with the grape berry moth.

GRAPE LEAF-HOPPER.

Throughout the United States and Canada, wherever the grape is grown, this small leaf-hopper (*Typhlocyba comes* Say) will almost invariably be found in greater or less numbers infesting the lower surface of the leaf, where it feeds and breeds, increasing in numbers as the season progresses, until by late summer and fall the vines are often literally swarming with it. Throughout its extended range the insect may be quite destructive in some localities nearly every year, and is likely to become so elsewhere at any time. The grape leaf-hopper is an insidious pest, often not noticed by the vineyardist until late summer and fall, when the yellow and brown-blotched leaves, falling prematurely, attract attention, by which time the injury has been done. The insects in feeding extract large quantities of liquid food, sucking it out from the interior of the leaf by means of their tube-like mouth-parts. When they are abundant this constitutes a heavy drain on the vitality of the plant. The injury to and loss of leaves prevents the proper assimilation of food by the vines; the fruit may be materially reduced in quantity and will lack much in flavor and sugar content. Although the yearly loss to grape growers from the attack of this species is sufficient to place it among the first-class pests of the vine, but little effort ordinarily is made to control it, perhaps principally because no very practicable remedy has until recently been proposed. In the literature of the species there are many records of serious outbreaks of the pest here and there over the country, and recently the insect has attracted more than usual attention on account of serious injury in the Chautauqua and Erie grape belts, where it has been carefully studied by Professor Slingerland.^a

Description and Life History.

The adult grape leaf-hopper is quite small, measuring not more than one-eighth of an inch in length. It is very agile, moving with almost equal facility in all directions, and flies out from the vines often in swarms upon slight disturbance. The general appearance of the insect is shown in figure 6, the back of the insect being marked with yellow or red, the exact pattern and color varying much among different individuals and according to season. There are numerous varieties of the insect based on these variations, several varieties often occurring together on the same vine, though more usually insects showing one type of color pattern will be found to predominate. The insect passes the winter in the adult condition in hibernation in trash in and near vineyards, in the edges of neighboring woods, in grass along gullies, in ditches, etc. Early in the spring the insects come from winter quarters and attack almost any succulent vegetation at hand. By the time the foliage of the grape appears they are out in large numbers and begin to infest the vineyards. These adult hoppers of the

^a Bul. 215, Cornell Agrl. Exp. Station (1904).

hibernating generation feed and breed on the lower or earlier-appearing leaves, gradually disappearing as the season progresses, but not before some of their progeny have reached the adult condition. Some weeks are spent by the adults in the spring in feeding before egg-laying begins. Eggs are placed just beneath the epidermis in the lower leaf surface, usually singly but also in groups of from 6 to 9, the egg stage, according to Professor Slingerland, lasting from 9 to 14 days. Egg-laying probably continues for two months or more. When just hatched the young hopper is very small, whitish in color, with red eyes, later becoming striped with yellow. In the course of their growth these nymphs molt four times, the white skins being very numerous on the lower surfaces of badly infested leaves, as shown in figure 6, at *g*. The nymphs feed in the same manner as the parents, sucking juices from the leaves, at first on the lower surface of the older leaves where they were born, but later spreading more or less generally over the plant. They are very agile,

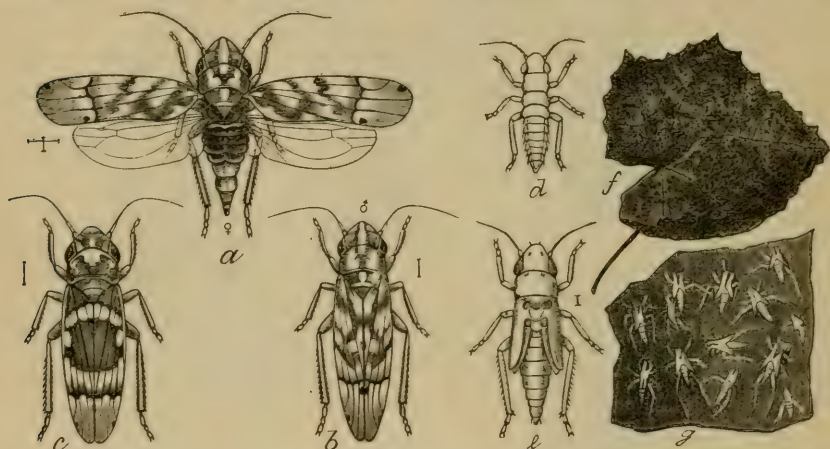


FIG. 6.—Grape leaf-hopper (*Typhlocyba comes*): *a*, Adult female; *b*, adult male; *c*, another form of the species, showing variation in markings; *d*, newly-hatched nymph; *e*, last stage nymph; *f*, appearance of injured leaf; *g*, cast pupa skins. *a-c*, Much enlarged; *g*, less enlarged; *f*, reduced. (From Marlatt.)

running in all directions, but do not leap or hop. In New York State Professor Slingerland found that from 30 to 35 days were required for their development in summer to the adult, and that there is but one full generation and a partial second brood of nymphs each year, the individuals of this partial second brood probably not maturing before frost. In warmer parts of the country two full generations or more are probable, since Gillette has shown this to be the case for Colorado and Townsend for New Mexico. By late summer the insects are often exceedingly abundant, and all stages are to be found on the leaves. The continued effect of their feeding is very apparent, the leaves being yellow and brown-blotched, the older ones most affected (figure 6, *f*). Feeding continues until the approach of cool weather, when the "hoppers" seek suitable hibernation quarters, as stated.

Remedial Measures.

The grape leaf-hopper has proved to be a difficult pest to combat successfully. Various practices have been proposed, such as the use of trap lanterns to burn at night, the raking and burning during winter of fallen leaves and trash in vineyards, the use of sticky shields or fans to catch the adults as they fly from the vine on being disturbed, and in California the use of insect nets for the same purpose.

Extensive field experiments were made by Professor Slingerland and his assistants in 1902 in Chautauqua vineyards against this pest, and fully recorded in Bulletin 215 already cited. He found that large numbers of the hibernated adults could be caught on sticky shields carried along each side of the row, the insects being frightened out by disturbing the vines. This work is done early in the season, before oviposition takes place to any extent. A light wooden frame is made, 7 or 8 feet long by 4 feet high. To the crosspiece at the bottom, which should be up from the ground about a foot, are fastened several stiff wires of the shape of a hayrake tooth. These are fastened so that the points curve inward and downward to the ground at base of plants when the shield is held in place beside the vines. The whole framework, including the wires, is covered with oilcloth which is coated with a sticky substance, made by using melted resin, 1 quart, and castor oil, 1 pint.

Early in the season the insects will be found mostly on the lower leaves and the frame need not be high. As the higher leaves are invaded the height of the frame must be increased. In controlling the insects in this way it is very important to catch the over-wintering adults before egg laying has begun, thus greatly reducing the number of progeny to appear later, and the operation of catching the insects must be repeated at frequent intervals.

Extensive tests with sprays were also made, and it was found practicable to destroy the young wingless hoppers or nymphs with a whale-oil soap solution, the soap being used at the rate of 1 pound to 10 gallons of water. The spraying must be done very thoroughly, covering the under surface of the leaves, as only those nymphs are killed which are actually hit with the spray. This work should be begun when it is observed that the young are becoming common. In the Chautauqua and Erie grape belts this will be early in July. There will be less foliage to treat at this time than if the work be deferred until somewhat later. Repeated applications may be necessary, especially if the work is not thoroughly done. It has been noted by Mr. Fred Johnson, of this Bureau, that whale-oil soap leaves a stain on the fruit at picking time, greatly lessening its market value for dessert purposes. It is likely that an 8 to 10 per cent kerosene emulsion could be used, which would obviate this difficulty, and would prove equally effective in killing the young hoppers.

Thorough cleaning up of fallen leaves and trash in vineyards during the winter will undoubtedly destroy many hibernating adults, and if this work be extended to adjacent areas where the insects are likely to find shelter, the reduction in their numbers will be materially greater. Where practicable the burning over of adjacent meadows, wood lots, and spaces along fences is very advisable. It has been observed that in vineyards in which clean culture is practiced, all grass and weeds being kept down throughout the season,

the "hoppers" are notably less abundant than where this practice is not followed. The absence of suitable hibernation quarters in the vineyard causes them, largely, to migrate elsewhere, and vineyards receiving such care are much less seriously infested the following spring and summer.

The grape leaf-hopper secures its food by sucking juices from the interior of the leaf, and arsenical poisons useful against the grape root-worm and the grape berry moth are quite useless against this pest.

GRAPE LEAF-FOLDER.

Observing grape growers have often noticed, especially during midsummer and later, grape leaves folded together, the interior (upper) surface of the leaf being more or less skeletonized, and within the fold a slender larva, which, upon being disturbed, is apt to wriggle out and fall or hang suspended by a thread. This insect, the grape leaf-folder (*Desmia funeralis* Hübner; see fig. 7), is widely distributed and a few are to be found in vineyards almost every year, while here and there throughout their range they may be so abundant as to do serious injury. There are two broods each year in the more northern States and three or possibly more in the South. The insect winters in the pupal stage in the folded and fallen leaves, the moths appearing in the spring shortly after the foliage puts out, and the eggs are placed in small patches here and there on the vine. Upon hatching, the young larvæ attack the foliage, folding the leaves as stated. Mr. Johnson has observed that larvæ of the

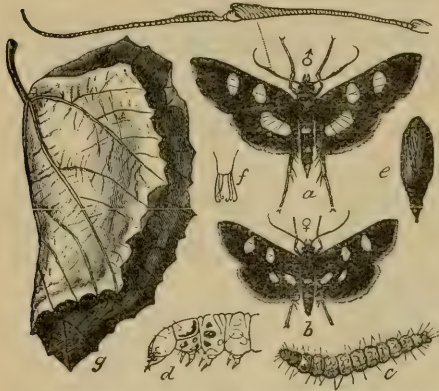


FIG. 7.—Grape leaf-folder (*Desmia funeralis*): a, Male moth and enlarged antenna of same; b, female moth; c, larva; d, head and thoracic segments of same, enlarged; e, pupa; f, tip of pupa, enlarged; g, grape leaf folded by larva. (From Marlatt.)

first brood may attack bunches of grape blossoms and young fruit in a way similar to the grape berry moth. In 3 or 4 weeks the larvæ are full grown and transform to pupæ within the folded leaves, moths emerging some 8 or 10 days later. By midsummer and fall the insects may become quite abundant, and in badly infested vineyards the folded leaves are everywhere in evidence and are quite conspicuous from the color of the lower surface. In the fall the larvæ pupate in the folded leaves and pass the winter in these on the ground.

Treatment.

Where the insects are but moderately abundant it will be quite practicable to search out the folded leaves and crush between the hands the larvæ or pupæ within. The destruction of the first brood in this way would greatly reduce the number of the insects later in the season.

Vines sprayed with arsenicals for the root-worm and the berry moth will be well protected from the leaf-folder, for in this way the majority of the leaves will be sufficiently poisoned to insure the destruction of the larvæ and prevent the folding of the leaves. After a leaf has been folded the larva is practically safe from poisoning. As the winter is spent in the pupal stage in the leaves on the ground, many of the insects may be destroyed by collecting and burning the fallen leaves, as recommended in the case of the grape berry moth and the leaf-hopper.

GRAPEVINE FLEA-BEETLE.

Early in spring, as the buds of the grape begin to swell and burst, these may be scooped out or entirely consumed by a small blue or greenish beetle (*Haltica chalybea* Illiger), measuring about one-fifth of an inch in length, of robust shape, with thick thighs, and jumping

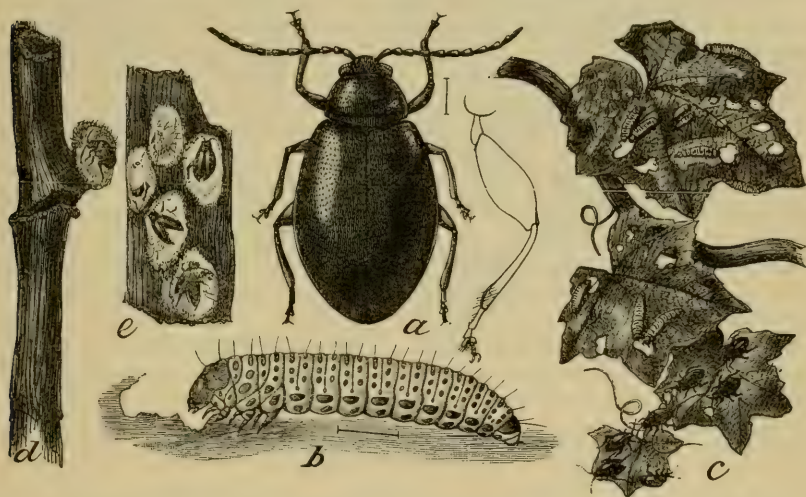


FIG. 8.—Grapevine flea-beetle (*Haltica chalybea*): a, Adult or beetle, with more enlarged leg at right; b, larva; c, larvæ and beetles on foliage; d, injury to buds; e, beetles killed by fungus. a, b, Much enlarged; c, d, e, about natural size. (From Marlatt.)

readily from the vines upon being disturbed (see fig. 8). When the beetles are abundant all of the buds on the vines may be quite destroyed, greatly retarding leafing out or even causing the death of the plant. Later the young foliage is eaten by the beetles, the females depositing their eggs more or less on the leaves, but largely, according to Slingerland,^a in cracks in the bark at base of buds, between bud scales, or even in the holes which have been eaten into the buds. The resulting larvæ feed on the leaves of the grape, mostly on the upper surface, and are thus readily destroyed with sprays. In 3 or 4 weeks the grubs have attained full growth; then, dropping to the ground, they make an earthen cell an inch or so below the surface, and transform to pupæ, from which the adult beetles will emerge in the course of 1 or 2 weeks. The new brood of beetles feeds upon the grape and other plants, going into hibernation in the fall and appearing the next

^a Bul. 157, Cornell Univ. Agrl. Exp. Station (1898).

spring to attack the buds of the grape, as stated. In the Northern States Slingerland's studies have shown but one generation of the insect each year. In the South two or more generations annually are supposed to occur, but definite evidence on this point is wanting.

The flea-beetle is native to North America, and occurs very generally throughout the eastern half of the United States, its western limits being Minnesota, eastern Nebraska, Kansas, and Texas. Its natural food is undoubtedly the wild grape, though numerous other plants are fed upon, as plum, apple, pear, quince, blue or water beech (*Carpinus*), elm, etc.

Treatment.

In vineyards which are regularly sprayed with arsenicals and Bordeaux mixture the flea-beetle will be effectively kept in check. The first application for the berry moth before the blossoms open, together with the application made after the blossoms fall, will destroy the larvæ, since these feed almost exclusively on the upper surface of the leaves. The insects thrive best in neglected vineyards, and may become quite abundant and destructive locally. Where it is desired to treat for this insect only, the vines should be thoroughly sprayed with an arsenical just as the buds are beginning to swell, or somewhat earlier. A close lookout must be kept for the first signs of the beetles, and the poison must be applied immediately. The delay of a day or so may mean the loss of the buds, and hence of the fruit crop. In the small home vineyard it will be practicable to search out the beetles and remove them by hand, doing the work in the morning when they are less agile. As stated, the destruction of the larvæ when feeding on the foliage later will be very easily accomplished by spraying with arsenicals.

It will also be quite practicable, as stated by Doctor Howard, to jar the beetles from the vines on canvas frames placed beneath, which should be kept saturated with kerosene.

ROSE-CHAFER.

About the time of blooming of the grape in the spring the rose-chaffer (*Macrodactylus subspinosus* Fabricius) may suddenly put in an appearance, often in enormous numbers, the long, spiny-legged, awkward, brownish beetles literally covering the plants, feeding at first upon the blossoms, but later attacking the young fruit and foliage, the leaves being eaten bare, except the larger veins (see fig. 9). This insect is a very general feeder; it attacks practically all fruits—e. g., apples, plums, cherries, peaches, etc.—as well as various vegetables, grains, and grasses. Many ornamental plants, such as *Spiræa*, *Deutzia*, and roses, are attacked, and its injuries to the last-mentioned have led to the use of the common name of "rose-chaffer" or "rose-bug," though it is perhaps now most commonly complained of from its injuries to grapes and other fruits. When abundant, the beetles may do serious injury in vineyards, quite destroying the blossom clusters or the newly set fruit. Berries not actually devoured are often so marked by the beetles that they become misshapen and crack as they grow, the seeds often protruding. After 3 or 4 weeks of feeding the beetles may disappear almost as suddenly as they came.

The rose-chaffer is rather widely distributed, occurring from Canada south to Virginia and Tennessee and west to Colorado. It is recorded also from Oklahoma and Texas, though west of the Mississippi it is apparently not very injurious. In the New England and Central States it is more abundant, and is most troublesome perhaps in New York, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, and Ohio, large outbreaks in ruinous numbers occurring more or less locally where the soil is light and sandy.

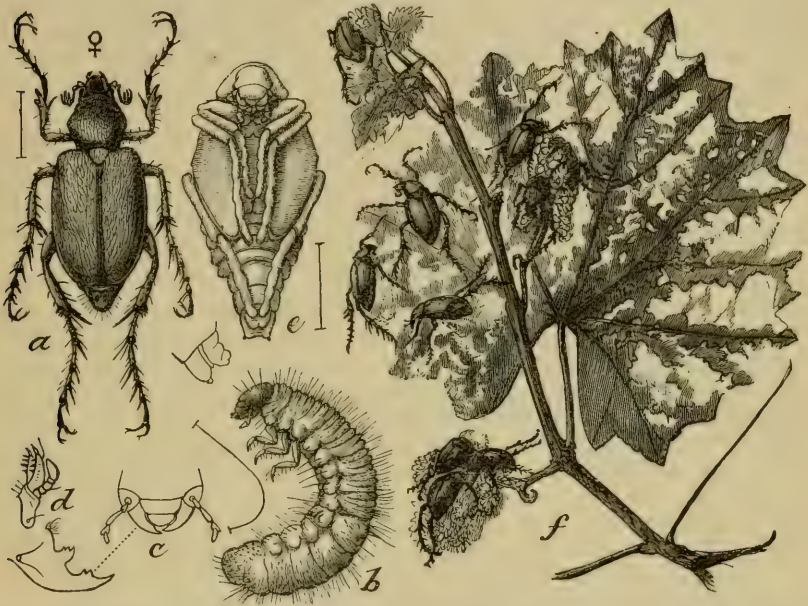


FIG. 9.—Rose-chaffer (*Macrodactylus subspinosus*): a, Adult or beetle; b, larva; c, d, mouth parts of same; e, pupa; f, injury to leaves and blossoms of grape, with beetles at work. a, b, e, Much enlarged; c, d, more enlarged; f, somewhat reduced. (From Marlatt.)

Breeding Grounds.

The insect lives in the larval stage underground, feeding on the roots of various plants, especially on the roots of grasses. Doctor J. B. Smith found larvæ in abundance in a vineyard in New Jersey and in a blackberry patch, feeding apparently on the roots of grasses and weeds which grew sparsely between the rows, and larvæ were still more numerous under the sod bordering the vineyard. In an adjacent meadow, where the soil was heavier and less sandy, no larvæ could be found. In general, the insects breed principally in light sandy soils, especially in meadow lands, but also in other places where there is more or less of growth of grass and weeds, and, to a less extent, in cultivated ground. Wet, clayey, or compact soils do not furnish desired conditions for the insects, and from the fact that they are largely confined to the lighter soils it becomes practicable to reduce them greatly by planting these to annual crops which receive thorough cultivation.

Life History.

The beetles deposit their eggs singly, burrowing beneath the soil, laying, according to Doctor Smith,^a from 12 to 20 eggs. The resulting larvæ feed upon the roots of various grasses and possibly weeds and other vegetation. They are mostly full grown by fall, and burrow below the frost line, where the winter is spent. With the coming of spring the grubs ascend toward the surface and enter the pupa stage, from which in from 10 to 30 days, varying with the temperature, the beetles develop and attack the grape and other plants, as stated. There is thus but one generation each year, the principal injury of the insect being done during the 3 or 4 weeks of its life as a beetle.

Treatment.

The rose-chaffer is an exceedingly difficult insect to combat successfully. When the insect occurs only in moderate numbers, arsenicals will be reasonably satisfactory; but when it occurs in swarms, the plants are reinfested as fast as the insects are killed. It is possible, however, that a heavy application of arsenate of lead, say 5 to 6 pounds to 50 gallons of water or Bordeaux mixture, will largely protect the vines, and this plan should be tested by vineyardists confronted with this pest. Very thorough applications should be made upon first signs of the insects and repeated as necessary. Many different substances have been applied to vines to render them obnoxious to the beetles, but none of these has proved to have any special value. Perhaps the method most generally relied upon is picking or jarring the beetles from the vines. In the latter work an umbrella-shaped frame with a canvas or oil cloth covering, with a can of kerosene at the bottom, is frequently used, being held under the vines, which at the moment are sufficiently shaken to cause the beetles to fall. Jarring or hand-picking must be done every morning, or, better, twice a day, during periods of severe infestation.

The numbers of this insect may be considerably lessened by restricting its breeding grounds. In vineyards on sandy or light soil especial care should be taken to keep the rows and surroundings free from weeds and grass, upon the roots of which the larvæ feed. Sandy meadow lands in the vicinity of vineyards should be broken up and cultivated to annual crops, and in this work the cooperation of vineyardists throughout a neighborhood is especially important.

Bagging grapes as soon as the fruit has set is often practiced, and affords protection not only against further injury from the rose-chaffer, but also from the grape berry moth, the grape curculio, and fungous diseases of the fruit.

INSECTICIDES.^b

ARSENICALS.

Arsenicals, applied in the form of a spray, are effective against the grape root-worm, the grape berry moth, the grape curculio, the grape leaf-folder, and other insects which devour the foliage

^a Bul. 82, N. J. Agrl. Exp. Station (1891).

^b For a more extended account of insecticides, see Farmers' Bulletin 127, U. S. Dept. of Agriculture, by C. L. Marlatt.

and fruit. The arsenical is best used as an ingredient added to the Bordeaux mixture, which is the standard remedy for the control of fungous diseases. When an arsenical is used simply in water the vineyardist should always add, to each 50 gallons of the liquid, the milk of lime made from slaking 2 to 3 pounds of good stone lime.

Paris green.—This is used at the rate of 1 pound to each 100 or 150 gallons of liquid, whether water and milk of lime or the Bordeaux mixture. Paris green should be worked into a paste with water before being added to the liquid in the spray tank, to prevent its adhering in small lumps. When used with Bordeaux mixture, the latter will probably serve to hold it well on the vines, giving results perhaps equal to those produced by arsenate of lead.

Scheele's green.—This arsenical is similar to Paris green, being the simple arsenite of copper containing no acetic acid, and hence considerably cheaper. It is a much finer powder than Paris green and remains in suspension longer. It is used in the same way and at the same strength recommended for the former poison.

Arsenate of lead.—There are now numerous brands of arsenate of lead on the market, and vineyardists should be careful to buy an efficient and safe kind. Some preparations sold as arsenate of lead contain an amount of free arsenic dangerous to foliage, and an unnecessary amount of water may also be present, thus lowering the quantity of poison when used at a given strength. A proper arsenate of lead should contain no free arsenic and should have as much as 50 per cent actual arsenate of lead. Arsenate of lead is used at the rate of 3 to 6 pounds to each 50 gallons of liquid, and, as it comes in the form of a putty-like paste, must be worked free in a little water in a bucket or other suitable vessel before it is added to the spray tank. It may be used much stronger than any other arsenical and it adheres well to the foliage. For these reasons it is preferred by many vineyardists.

Arsenite of lime.—This is much the cheapest of the arsenical poisons. On apple it is stated to be very satisfactory, and it should be equally so on grape. It seems not yet to have been used to any extent on grape, and should be tried first in a small way. It may be prepared at home according to the following formula:

White arsenic.....	pounds..	1
Sal soda crystals.....	do.....	4
Water.....	gallon..	1

All of the ingredients are boiled together for a few minutes or until dissolved, and any water lost by evaporation should be restored. This constitutes a stock solution, 1 pint being used with each 40 or 50 gallons of Bordeaux mixture. When it is used in water the vineyardist must add the milk of lime made from slaking 2 to 3 pounds of good stone lime, which is necessary to produce the arsenite of lime.

CONTACT REMEDIES.

For insects which secure their food by sucking the juices from the plant, such as the grape leaf-hopper and aphides, contact insecticides must be used. Two such insecticides are whale-oil soap solution and kerosene emulsion. These preparations are not ordinarily used in Bordeaux mixture. They are sprayed on the vines in the usual way.

Whale-oil soap.—For vines in foliage, whale-oil soap is used at the rate of 1 pound to 8 or 10 gallons of water. There are several grades of this article on the market, but a potash whale-oil soap is best, especially one that does not contain more than 30 per cent of water.

Kerosene emulsion.—This doubtless will be equally satisfactory as a spray against the grape leaf-hopper, and may be prepared as follows:

Whale-oil or other soap.....	pounds..	2½
Kerosene (150 flash test).....	gallons..	5
Water to make.....	do.....	50

The soap is dissolved in 6 to 8 gallons of hot water, and the kerosene is at once added. The whole is then thoroughly emulsified by the use of a hand pump, pumping the liquid back upon itself for 8 or 10 minutes or until a creamy-white emulsion results. This, when diluted with the required amount of water, will contain 10 per cent of kerosene, which strength should be effective in destroying young hoppers without injuring the foliage or the fruit. If a smaller quantity of emulsion than 50 gallons is desired, it may be made, simply observing the proportions given.

FUNGOUS DISEASES.

The fungous parasites of the American varieties of grape are indigenous, and came originally from the native wild vines. With the gradual extension and development of the grape-growing industry there has also been an increase in the distribution and destructiveness of these fungous diseases. The conditions which necessarily obtain in commercial grape culture have disturbed the equilibrium which had become established between the vine and its parasites in their wild state, and have facilitated the production and distribution of the diseases. In the selection and breeding of the grape attention has been devoted chiefly to the improvement of the fruit, and this has apparently resulted in a decrease of the natural powers of resistance to disease originally possessed by the wild vines.

In certain sections of the country where grape growing was once a profitable industry it has largely been abandoned, chiefly on account of the great loss caused by disease. The amount of loss from fungous diseases of the grape in the eastern half of the United States during the past season (1906) is estimated at from 15 to 20 per cent of the entire crop. In some localities it reached 40 to 50 per cent, and in some particular vineyards where there was promise of a crop of 4 or 5 tons per acre the loss was total, while in one favored region the loss was not over 5 per cent.

Injury due to fungi depends largely upon weather conditions. The conditions most favorable for the development of the majority of the fungous diseases are excessive moisture and heat. The general physiological condition of the vines is also important. Vines which are kept thrifty and vigorous by proper care and cultivation are not

likely to suffer so severely from most diseases as those which are neglected.

The principal fungous diseases in the order of their importance are black-rot, downy mildew, powdery mildew, anthracnose, and ripe-rot. There are also other diseases, which will be referred to later, but they are either not of sufficient importance to deserve much attention here or else their treatment is not yet satisfactorily determined.

BLACK-ROT.

Black-rot is the most generally distributed and destructive fungous disease of the grape in the region east of the Rocky Mountains. It is caused by a parasitic fungus known as *Guignardia bidwellii* (Ell.) V. & R. It gains entrance to the plant by means of minute germs called spores. These are borne in small black spore cases, and can

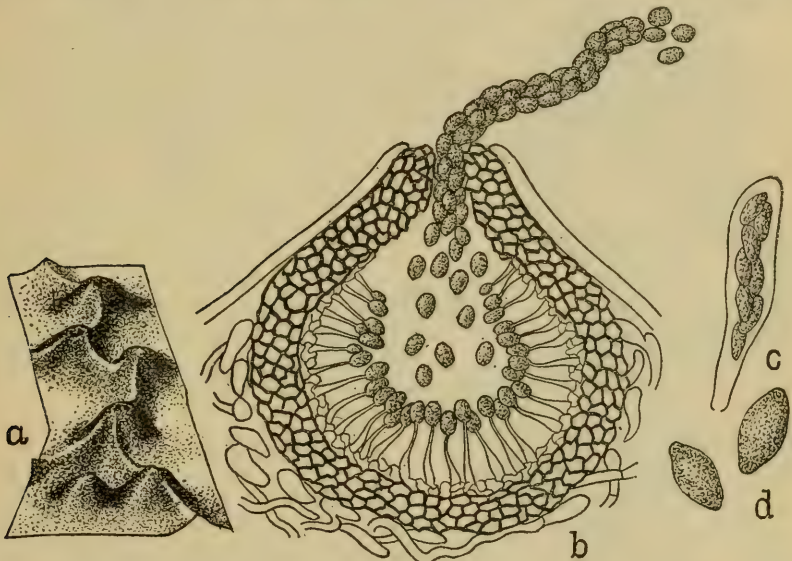


FIG. 10.—The black-rot fungus (*Guignardia bidwellii*): a, A portion of an affected grape, showing the pustules in which the spores are produced (slightly magnified); b, a section of one of these pustules very highly magnified, showing the manner in which the summer spores are produced and discharged; c, a sac containing winter spores; d, single winter spores very highly magnified.

not be seen with the naked eye. They are distributed chiefly by the wind and rain. Two or more forms of spores are produced, as shown in the accompanying illustration (fig. 10, b). When these spores come in contact with the young and tender parts of the vine, under favorable conditions, they germinate and produce a slender tube, which penetrates the tissue and may destroy it.

This disease attacks the leaves and shoots, as well as the fruit. It usually makes its first appearance on the leaves and young shoots, producing reddish-brown dead spots. The fruit may be attacked when young, but usually the disease does not attract attention until the berries are half grown or more. Brown or blackish spots first

appear; these spread and soon affect the whole berry, which becomes black and shriveled, as shown in the accompanying illustration (fig. 11). These diseased berries remain attached to the vine, and their surfaces become covered with minute black pustules, which contain the summer spores of the fungus. During the winter and spring another form, called the winter, or resting spore, is produced upon these old, shriveled berries (fig. 10, *c, d*). These spores help to carry the disease over from one season to another. This fact would indicate the desirability of destroying, by burning, all diseased fruit, as well as leaves and prunings, as early in the spring as possible.

Treatment.

This disease can be effectually controlled by thorough spraying with Bordeaux mixture. Five or six applications are usually necessary during the season, the first being made just before the buds open. For the last one or two applications, some fungicide which does not stain the fruit should be used. Burgundy mixture is recommended for this purpose. Full directions regarding the preparation of the fungicides and the times of application will be found later.

Covering the bunches of grapes with paper bags soon after the blossoms fall is a means of preventing black-rot and most other fungous parasites. It is usually regarded as too laborious and expensive for large vineyards, but may be profitably practiced where only a small number of vines are grown.

DOWNY MILDEW.

Downy mildew (*Plasmopara viticola* (B. & C.) Berl. & De Toni) in certain seasons and in northern localities sometimes causes more loss than black-rot and is a close rival for first place among the fungous enemies of the grape. It attacks all the tender growing parts of



FIG. 11.—A bunch of grapes destroyed by black-rot.

the vine. Usually it is at first most noticeable on the foliage, producing greenish yellow, irregular spots upon the upper surface, which become reddish brown. At the same time there appears on the under surface of the leaf a thin, loose, white, downy growth, suggestive of hoar frost (fig. 12). This growth consists of the fertile fungous filaments bearing the summer spores (fig. 13, *a, b*), which under favorable conditions are distributed by the wind and water to the berries and other parts, where they germinate, penetrate the tissues, and continue their destructive work. The young shoots are also frequently attacked and killed.

The fruit, if attacked when young or only partly grown, shows first a brownish spot, and later becomes covered with the gray, downy growth of the fungus. This form of the disease is sometimes called "gray-rot" by vineyardists (fig. 14). When the berries escape the disease until they are half grown or more it appears as a brownish or brownish purple spot which spreads and soon involves the whole berry. The affected fruit becomes soft and wrinkled and falls to the ground when disturbed. This stage of the disease is sometimes called "brown-rot."



FIG. 12.—A grape leaf attacked by the downy mildew (*Plasmopara viticola*), showing the appearance of the leaf above and below.

Besides the summer spores mentioned, there is also produced within the diseased tissues another form of reproductive body, sometimes called a winter, or resting, spore (fig. 13, c). These spores are produced in much smaller numbers than the summer spores and are provided with a rather thick, dark-colored outer covering apparently intended for their protection during the winter.

This disease, like the black-rot and many others, develops most rapidly and does most injury during hot, wet weather.

Treatment.

It is desirable to destroy as many as possible of the diseased leaves, shoots, and berries, which may contain the winter spores. Thorough spraying, as recommended for the black-rot, will effectually control this disease.

POWDERY MILDEW.

The powdery mildew (*Uncinula necator* (Schw.) Burr.) rarely causes great loss to American varieties of grapes. It is most severe on the European, or vinifera, grapes. This mildew belongs to a group of fungi quite different from the downy mildew.

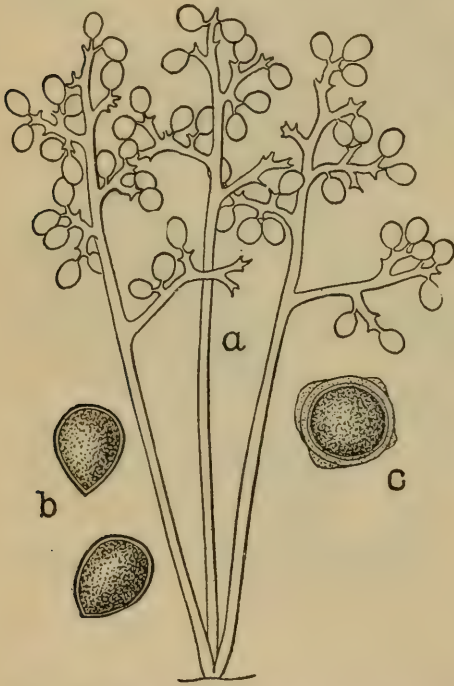


FIG. 13.—The fungus causing downy mildew: *a*, Fertile filaments of the downy mildew fungus, showing the manner in which the summer spores are borne; *b*, two summer spores; *c*, a winter, or resting, spore. (All highly magnified.)



FIG. 14.—A bunch of young grapes partially destroyed by "gray-rot." This is a form of the downy mildew affecting the very young fruit.

It differs from all other parasites which attack the grape in its superficial habit of growth. The filaments of the fungus do not invade the tissues of the plant to destroy them. The parasite obtains its nutriment by means of sucker-like organs which penetrate the cell walls of the surface layer of tissue only. The fine, white filaments of the fungus, which constitute the vegetative portion of the parasite,

spread over the surface of the leaves, shoots, and fruit, and send up short, irregular branches upon which immense numbers of summer spores are produced in short chains (fig. 15, *a*). These are most noticeable upon the upper surface of the leaf, giving it a fine gray, powdery, or mealy appearance. Finally the affected part of the leaf becomes light brown, and if the disease be severe the leaves fall. The fungus produces a similar appearance upon the young shoots. Berries which are attacked take on a gray, scurfy appearance, become specked with brown, and fail to develop further. Affected grapes when nearly half grown sometimes burst open on one side, exposing the seeds. The fruit does not become softened and shrunken as when attacked by the downy mildew.

Besides the summer spores, winter, or resting, spores are also produced in the latter part of the season. These are borne in sacs which

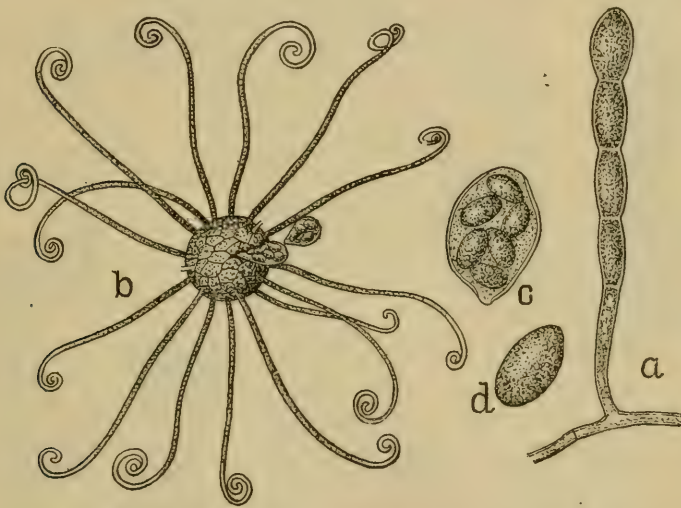


FIG. 15.—The fungus causing powdery mildew (*Uncinula necator*): *a*, A fertile filament of the fungus bearing a chain of summer spores; *b*, a spore case, in which the winter or resting spores are produced; *c*, a single sac containing winter spores; *d*, a single winter spore. (All highly magnified.)

are inclosed in minute black, globose fruiting bodies furnished with slender appendages curled at their tips (fig. 15, *b*, *c*, *d*). These black spore cases are so small that they can scarcely be seen with the naked eye, but by the aid of a hand lens they can be easily observed. The powdery mildew is usually more prevalent during dry, hot seasons than in wet ones. It differs in this respect from most of the other grape diseases. In California this is the principal fungus disease of the grape.

Treatment.

Bordeaux mixture, as recommended for the black-rot, will prevent this disease. Where this trouble alone is to be combated it may be successfully done by dusting with flowers of sulphur. East of the Rocky Mountains, however, it should be treated with Bordeaux mixture, as it is rarely likely to occur alone.

ANTHRACNOSE.

Anthracnose (*Sphaceloma ampelinum* De By.) has also been called "bird's-eye rot," on account of the peculiar spots it produces upon affected grapes. Like most of the other diseases of the grape, it attacks the leaves and shoots as well as the fruit. On the leaves it at first appears as minute, irregular, dark brown, slightly sunken spots, having a darker margin. These spots usually become lighter colored when old, and frequently crack or fall out, leaving irregular holes in the leaves. This disease presents much the same appearance on the shoots as on the leaves, though the spots are frequently larger and more sunken (fig. 16). They also tend to run together and form irregular patches.



FIG. 16.—Grape shoot, showing spots produced by anthracnose (*Sphaceloma ampelinum*).

the diseased area to rupture and the seeds to become exposed. The bursting of the berries and the exposure of the seeds may, however, be produced by other causes,

The disease is most characteristic and conspicuous upon the fruit. The spots are usually brown at first and surrounded by a narrow, dark purplish margin; they increase in size and gradually become grayish white and somewhat sunken. Frequently two or more spots unite and cover a considerable part of the berry (fig. 17). The affected tissues do not become softened, as in the case of the downy mildew, but the fruit becomes hard and more or less wrinkled. If only a small part of the berry is affected it may continue to grow, causing



FIG. 17.—Portion of a bunch of grapes, showing the effect of anthracnose.

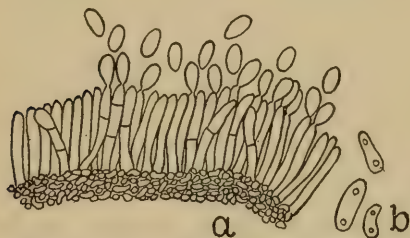


FIG. 18.—Section of an anthracnose spot, highly magnified: a, Showing the way in which the spores are borne; b, three of these spores more highly magnified.

such as the powdery mildew and certain physiological disturbances.

On the diseased areas the minute spores or germs of the fungus are frequently produced in immense numbers. The way in

which these spores are borne is shown in figure 18. No special winter form of spore is known to be produced by this fungus. The fine, thread-like filaments which constitute the vegetative part of the parasite live during the winter in the tissues of the vines and are ready for active growth in the spring.

The anthracnose is quite widely distributed in this country, but

fortunately has not caused any great general loss. It should be carefully watched, however, as, when once well established under favorable conditions, its eradication is very difficult.

Certain varieties, such as Diamond, Brighton, Agawam, and Salem, are especially susceptible to this disease.

Treatment.

All diseased shoots should be cut and burned, as it is believed that it is through these that the disease is chiefly transmitted each season. Spraying with Bordeaux mixture, as recommended for black-rot, when accompanied by thorough cutting and burning of diseased parts, is likely to prove sufficient, except where the disease is unusually severe, in which case the treatment which has been adopted and found very successful in Europe may be followed. This consists of the application of the following mixture:

Sulphate of iron (copperas)	pounds..	110
Sulphuric acid, commercial.....	quart..	1
Hot water	gallons..	26

First pour the acid upon the copperas and then add the water. This mixture should be prepared and handled with great care, as it is exceedingly caustic and will injure the skin, clothing, and almost everything with which it comes in contact. On this account it can not be applied with a common spray pump. A swab, made by attaching a bundle of rags to a stick, may be used in applying the mixture. All portions of the vines should be thoroughly covered with this preparation just before the buds begin to swell in the spring.

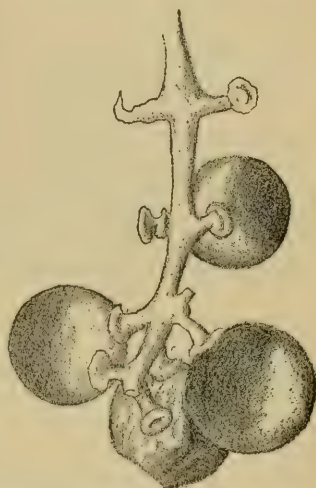


FIG. 19.—Grapes attacked by the ripe-rot (*Glomerella rufomaculans*).

RIPE-ROT.

Ripe-rot (*Glomerella rufomaculans* (Berk.) Spauld. & von Schrenk) has also been called bitter-rot. The name bitter-rot is, however, applied to another fungous disease of the grape, caused by *Melanconium fuligineum*. As the present name indicates, the disease usually appears on the fruit when the latter is nearly mature, and under fa-

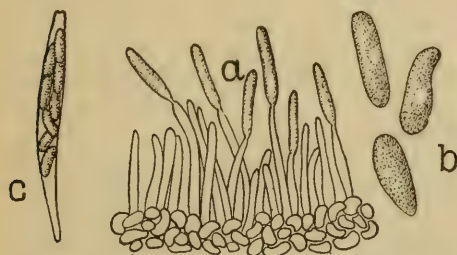


FIG. 20.—The fungus producing ripe-rot (*Glomerella rufomaculans*): a, Summer spores, showing the manner in which they are borne; b, the same spores, more highly magnified; c, a sac containing winter spores.

vorable conditions continues its development and destruction after the grapes are picked. It also attacks the leaves and stems, but is most noticeable and injurious on the fruit. The first indication of the disease is the appearance of reddish-brown discolored spots (fig. 19),

which spread and finally extend over the whole fruit. The surface then becomes dotted with dark, slightly elevated pustules, in which the spores are borne (fig. 20, *a*; *b*.). At this stage of development this disease is not easily distinguished from the early stages of black-rot and bitter-rot. The berries do not shrivel up, however, as in the case of the black-rot, and usually are easily detached from the bunch. The spores mentioned are produced in large numbers and serve to spread the disease.

The fungus causing this disease is closely related to that which produces the bitter-rot of the apple, and by some is regarded as the same; but no entirely conclusive cross-infection experiments have yet been reported. The Department of Agriculture has demonstrated by means of pure cultures of this fungus that there is another stage, producing spores very similar in appearance to those just mentioned, but borne in sacs which are inclosed in spore cases similar to those of the black-rot fungus (fig. 20, *c*). This spore form is of very infrequent or doubtful occurrence in vineyards, and is probably not an important factor in the distribution of the disease.

It is difficult to determine how much injury is done by this disease on account of the liability of confusing it with other fungous troubles. It is quite generally distributed, and may cause more loss than is usually attributed to it.

Treatment.

Spraying as recommended for black-rot will largely prevent this disease. The later applications are especially important and should be very thorough.

LESS IMPORTANT DISEASES.

Bitter-Rot.

The bitter-rot of the grape is caused by a fungus known as *Melanconium fuligineum* (Scrib. & Viala) Cav. Fruit attacked by this disease presents an appearance quite similar to that produced by the ripe-rot. Bitter-rot is no doubt sometimes confused with other diseases. It is mostly restricted to the Southern States, and is not generally regarded as serious.

Treatment.—Spraying as for black-rot will probably prevent this disease.

White-Rot.

The effect of the disease known as white-rot (*Coniothyrium diplo-diella* (Speg.) Sacc.) upon the fruit of the grape is somewhat similar to that of the brown-rot form of the downy mildew. It occurs in Missouri and the Southwest and has been reported as rather serious in some parts of Ohio.

Treatment.—There is nothing in the nature of this disease, so far as known, to indicate that it can not be satisfactorily controlled by the treatment recommended for black-rot. Sufficient knowledge of this subject to justify a positive statement in regard to treatment is not at present available.

Crown-Gall.

Crown-gall is a disease of somewhat uncertain origin, characterized by the formation of rough outgrowths, or excrescences, on the vines, usually near the surface of the soil. Certain forms at least are known to be contagious.

Treatment.—All plants bearing galls should be burned, and great care should be exercised to avoid planting diseased stock. Fungicides are apparently useless in combating this disease.

Root-Rot.

The roots of the grape are known to be attacked by several different fungi, especially when the root system has become weakened or injured by other causes. Two forms of root-rot are of sufficient importance to be mentioned here.

Vibrissea hypogæa.—The fungus known as *Vibrissea hypogæa* Ch. Richon & Le Monnier is usually associated with insect injury, caused either by Phylloxera or by the grape root-worm. It has been found in New York, Pennsylvania, and Missouri, and appears to hasten the death of plants, especially those on which the root-worm has been at work.

Treatment.—This root-rot can be prevented only by the destruction of the insects which injure the root system and thus give the fungus opportunity to gain a foothold.

Ozonium.—There is a root-rot of a more serious nature prevalent in and chiefly restricted to Texas and New Mexico. This is caused by a fungus known as *Ozonium*, which also attacks the roots of cotton and a great variety of other plants. It is most destructive in the black waxy, clay soils, which are very poorly aerated. Plants attacked die suddenly, the leaves and fruit withering up in a day or two and remaining on the vines.

Treatment.—No remedy is known for this root-rot of the grape. Soil upon which other plants have died with the same disease should be carefully avoided in planting vines.

Shelling.

The shelling or dropping of grapes from the bunches before maturity may be due to various causes. In some localities in New York and Pennsylvania this trouble is rather serious. The cases which the Department has had an opportunity to study have been found to be due mostly to an imperfectly known fungous disease, which appears to be induced chiefly by improper pruning and training. Allowing the vines to produce too heavy crops is also likely to increase this trouble. The subject is at present under investigation, and it is hoped to treat it separately in a later publication.

FUNGICIDES.

BORDEAUX MIXTURE.

Bordeaux mixture is the most efficient fungicide for general use at present known.

The 5-5-50 formula.—For ordinary use in combating grape diseases the following formula has given excellent results:

Copper sulphate (bluestone or blue vitriol).....	pounds..	5
Fresh stone lime.....	do.....	5
Water.....	gallons..	50

At least 100 gallons of the mixture are generally prepared at one time. This amount can be made by using twice the quantity of each material directed to be used for 50 gallons, and for 150 gallons three times the quantity must of course be used.

The 4-4-50 formula.—A somewhat weaker mixture, prepared according to this formula, has been successfully used in some cases and may perhaps prove generally satisfactory if properly made and thoroughly applied:

Copper sulphate.....	pounds..	4
Stone lime.....	do.....	4
Water.....	gallons..	50

The 6-3-50 formula.—Bordeaux mixture for use before the buds open in the spring should be prepared according to this formula:

Copper sulphate.....	pounds..	6
Stone lime.....	do.....	3
Water.....	gallons..	50

For applications to dormant vines a simple solution of copper sulphate is often used, consisting of 4 pounds of copper sulphate to 100 gallons of water. The strong Bordeaux mixture is more efficient, however, as it adheres better to the vines and is effective for a longer period.

PREPARATION OF BORDEAUX MIXTURE.

Failure to secure satisfactory results from the use of Bordeaux mixture is frequently due to lack of proper care and thoroughness in its preparation, or to the use of poor material. All ready-made preparations of Bordeaux mixture in the form of a paste or a dust should be avoided, as the chemical constituents do not properly combine in these conditions. A definite chemical compound is desired, and this can only be produced in proper form and condition by carefully following the directions given below.

Stock Solutions.

In order to carry on the work with the greatest convenience and economy, a considerable quantity of copper sulphate and of lime should be ready for immediate use. The copper and the lime may be prepared and kept most conveniently in the following manner:

Copper sulphate solution.—Take 100 pounds of copper sulphate (bluestone), place it in a gunny sack, and suspend it in a 50-gallon

barrel of water. Kerosene or whisky barrels will be found very convenient. The copper sulphate will all dissolve in from 12 to 18 hours if suspended in a loosely woven sack, but if it is thrown loose in the bottom of the barrel it will take several days and considerable stirring to dissolve it. This makes a solution containing 2 pounds of copper sulphate to each gallon of water. This may be kept as long as desired without deterioration, if covered so as to prevent evaporation.

Lime solution.—The various kinds of ground and prepared lime can not always be relied upon; stone lime is therefore to be preferred, and is more likely to give uniformly satisfactory results. Slake 100 pounds of stone lime in a 50-gallon barrel, adding the lime in small quantities with plenty of water and mixing thoroughly. When the lime is all slaked fill the remainder of the barrel with water. You will now have a stock preparation of lime which when thoroughly mixed will be thin enough to dip and pour readily. Each gallon of this preparation will contain 2 pounds of the stone lime. This may be kept under cover and used as needed. Where large quantities of material are being used it is desirable to have two or more barrels each of stock lime and bluestone instead of one, so that the bluestone in one barrel may be dissolving while that in the other is being used.

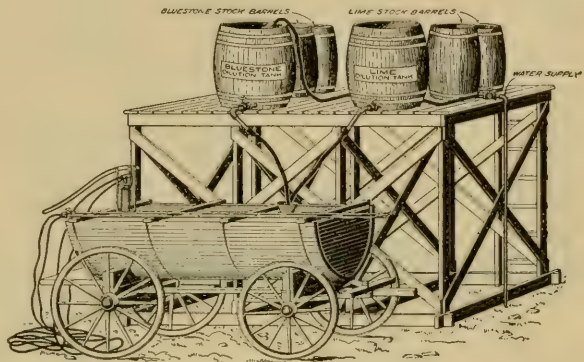


FIG. 21.—Elevated platform for making Bordeaux mixture. The water supply is merely indicated. In the absence of a water supply in pipes a water tank may be used. The materials flow by gravity directly into the spraying tank, which thus serves as the mixing tank.

Mixing Copper Sulphate Solution and Lime Solution.

To prepare a 100-gallon spray tank of Bordeaux mixture, take two 50-gallon barrels and fill them nearly full of water; to one barrel add 5 gallons of the bluestone stock solution, which will be the equivalent of 10 pounds of bluestone. To the other barrel add 5 gallons from the barrel of the stock lime preparation, which will be equal to 10 pounds of stone lime. Mix the lime thoroughly and allow the contents of the two barrels to run together into a trough, or through hose attached at the bottom of the barrels into the tank of the sprayer, as shown in the illustration (fig. 21).

If an insecticide is to be used, it may now be added to the mixture.

After the mixture is prepared it should be used very soon, and not be allowed in any case to stand more than a few hours before using.

The quantities mentioned in this account of the preparation of Bordeaux mixture will give 100 gallons of the 5-5-50 formula. For the other formulas, the manner of preparation is precisely the same, and the necessary changes in quantities of bluestone and lime are easily calculated.

Straining.

In order to avoid clogging the spray nozzles the mixture must be thoroughly strained before it goes into the sprayer. A strainer of brass wire cloth, 20 or 22 meshes to the inch, should be used for this purpose. A very convenient and satisfactory strainer is shown in the accompanying illustration (fig. 22). It consists of (1) a tight

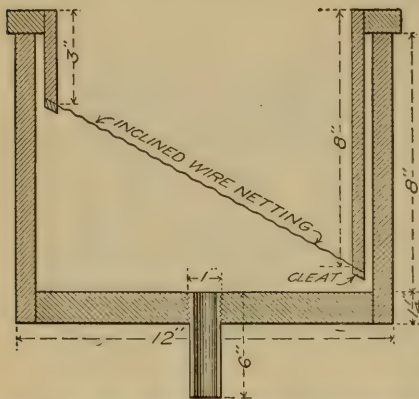


FIG. 22.—Cross section of strainer for Bordeaux mixture. The inner frame with inclined wire strainer fits loosely into the outer box.

outer box about 1 foot square, with a heavy bottom, into which a piece of $1\frac{1}{2}$ to 2 inch gas pipe is fitted as an outlet, and (2) an inner box, smaller and lighter, which will drop easily into the outer one. The wire cloth, securely fastened, forms the bottom of the inner box, and is sloped at an angle of about 30 to 35 degrees. The slanting of the sieve prevents clogging, and the removability of the inner box greatly facilitates cleaning. A narrow strip should be nailed about the outside of the inner box at the top, so as to prevent its dropping too far down; this will facilitate its removal.

Elevated Platform.

A platform similar to the one shown in the accompanying illustration (fig. 21) will be found very convenient in handling the stock solutions and the mixture. This should be located near a good water supply. A tank elevated above the mixing platform and filled by a windmill pump will be found very convenient, or the platform may be located beside a stream or spring and the water be raised by means of a force pump.

NONSTAINING PREPARATIONS.

Bordeaux mixture, when used late in the season, is apt to stain the fruit more or less and interfere with its sale. It is therefore best to use for the final applications some other fungicide which is not open to this objection. The amount of the mixture which may adhere to the grapes at the time they are picked is not sufficient to injure the consumer under normal or average conditions. Consumers, however, object to stained fruit, and this fact must be taken into account.

The following preparation, though not quite so efficient a fungicide as Bordeaux mixture, does not stain the fruit, and should, therefore, be used for the last two applications.

Burgundy mixture (copper carbonate mixture).

Copper sulphate	pounds..	2
Sodium carbonate (sal soda)	do.....	3
Water.....	gallons..	100

Dissolve and dilute each of the two chemicals to 50 gallons and allow them to run together into the spray tank in the same manner as in making Bordeaux mixture.

Insect poisons should not be added to this mixture.

Ammoniacal copper carbonate has been recommended in previous Farmers' Bulletins as a nonstaining application. Copper acetate has also been suggested for the same purpose. According to our present knowledge Burgundy mixture is about as safe and efficient as either of these and costs less than half as much.

A simple solution of copper sulphate, using 1 pound to 100 gallons of water, is frequently used for the final applications, but is much inferior to the Burgundy mixture.

SPRAYING.

SPRAYING APPARATUS.

The selection of a spraying outfit is a very important matter and should be carefully considered by anyone who is about to undertake this work. It will be found far better in the end to invest a larger amount at the start than to purchase a cheap outfit which may not be best adapted to the work and may prove a source of vexation, delay, and expense.

Good machines are frequently ruined in a few seasons by lack of proper care. It will be found a great saving of time and expense to wash out the spray tank, pump, and nozzles thoroughly after using and keep the machine under cover. The packing of the pump should also be looked after frequently.

The three most essential factors concerned in the operation of spraying are the power, the pump, and the nozzle.

Power.

Hand-power, horse-power, carbonic-acid gas, compressed air, and engines run by steam, gasoline, and kerosene are all used for spraying. In order to produce a satisfactory mist-like spray the power must be constant and sufficient to keep up the necessary pressure.

Hand-power.—Excellent work can be done by hand-power, using a knapsack or barrel pump (figs. 23, 24), but the time and labor required make it objectionable in large vineyards. In small vineyards it may be used to advantage.^a

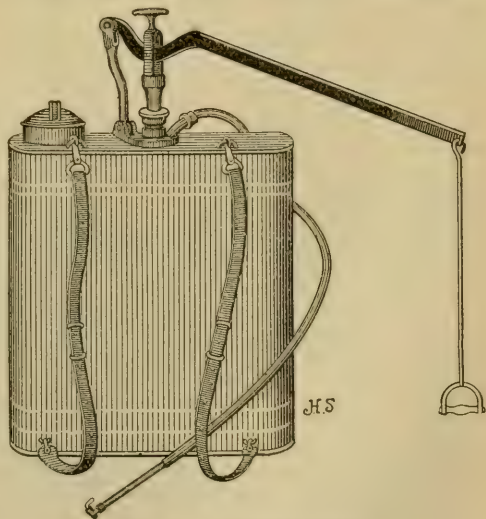


FIG. 23.—A knapsack sprayer.

^a For a general discussion of spraying machinery see Farmers' Bulletin 243, Fungicides and Their Use in Preventing Diseases of Fruits, by M. B. Waite.

Horse-power.—Used in connection with a geared sprayer, horse-

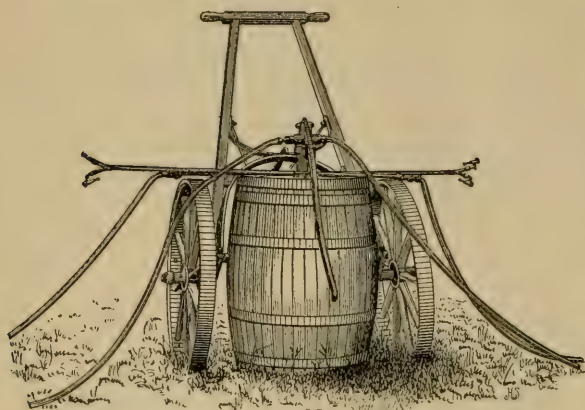


FIG. 24.—A barrel and cart spraying outfit.

power is in very general use in vineyards. There are a number of forms of these sprayers on the market, most of which are unsatisfactory, as it is not always possible to keep up sufficient and uniform pressure without driving so fast that the vines can not be properly covered with the mixture. One of these machines is shown in figure 25.

This, with the addition of the two nozzles directed downward from above, does fairly good work.

Carbonic-acid gas furnishes excellent power and does entirely satisfactory work in spraying. The pressure can be easily controlled and there is no pump to get out of order. It is considered somewhat more expensive than horse-power or gasoline power, however, and unless one is so situated that the drums can be recharged promptly, serious delays may occur which will interfere with the success of the work. A gas spraying outfit is shown in figure 26. A smaller tank mounted on a two-wheeled cart is also used.

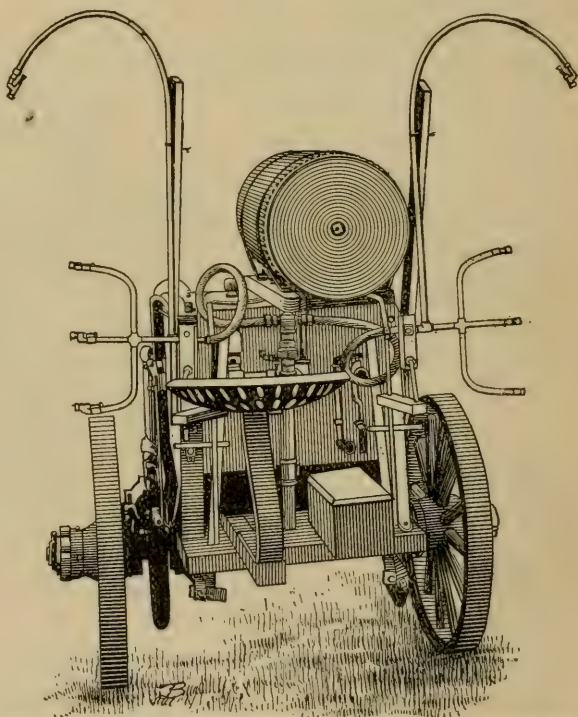


FIG. 25.—A geared horse-power vineyard sprayer. This is provided with a compressed air tank and an extra nozzle on each side directed downward in order to spray the tops of the vines.

Compressed air is used in the same way as gas (fig. 27). The air

is compressed by means of a stationary engine and air pump. Excellent work may be done with such a machine. The relative expense of this as compared with other forms of power has not, so far

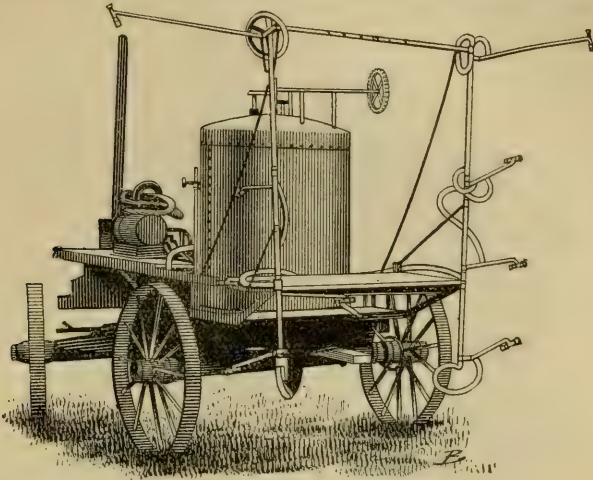


FIG. 26.—A carbonic-acid-gas sprayer.

as we know, been accurately determined. It is, however, preferred by some growers.

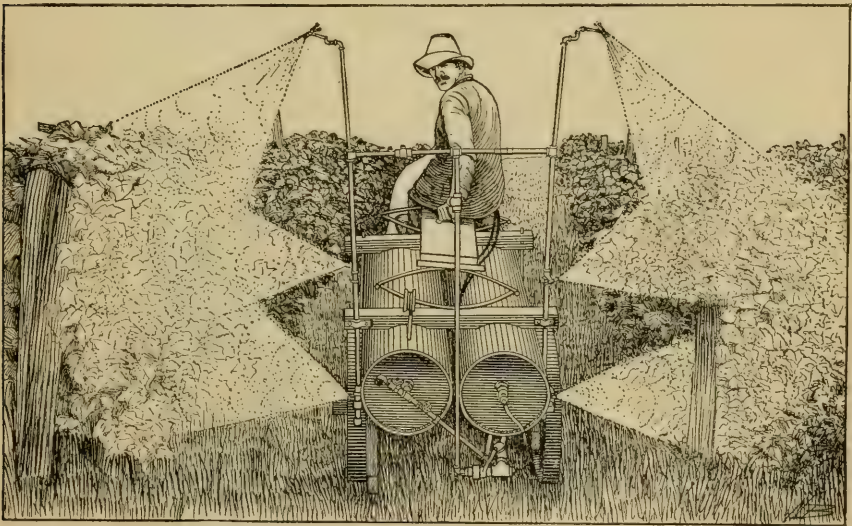


FIG. 27.—A compressed-air sprayer in operation.

Gasoline.—Steam engines are sometimes used, but they are usually found too bulky and heavy for vineyard work. Alcohol has not yet apparently been used in this connection. A cheap denatured

alcohol may perhaps eventually replace gasoline. At present, however, gasoline furnishes the most convenient and economical power. A compact and strong engine of two or three horsepower, with pump made especially for spraying purposes, will be found most

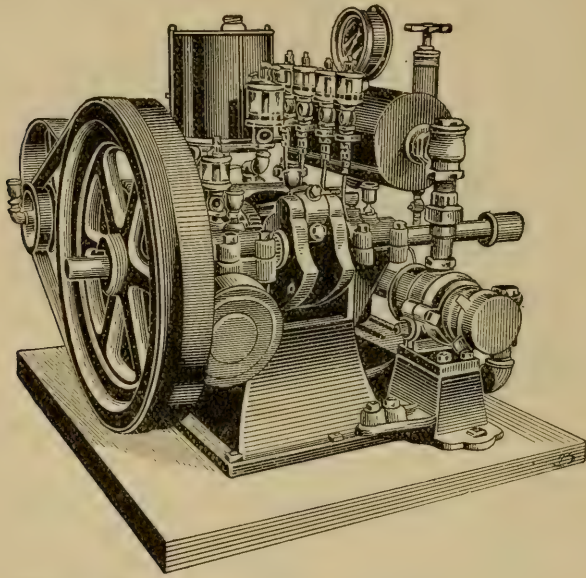


FIG. 28.—A gasoline engine and pump made especially for spraying.

satisfactory (fig. 28). Such an engine mounted upon a light handy wagon similar to that shown in figure 29, with a tank holding 100 to 150 gallons and fitted with adjustable rods and nozzles (fig. 30), would perhaps make the most efficient and economical outfit for

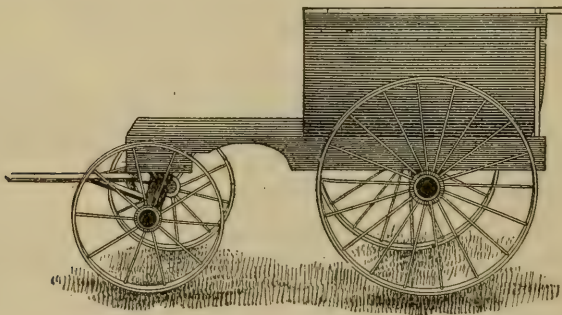


FIG. 29.—Wagon and tank adapted to vineyard spraying. A gasoline engine may be fitted in front and the upright adjustable rods and nozzles shown in figure 30 added.

extensive vineyard use. With such an outfit one may drive slowly and cover the vines and foliage thoroughly. If one has orchard fruit to spray, an engine is still more desirable. It may also be used for other purposes about a place.

Pumps.

The pump is a very important part of a spraying outfit. It should be strongly and carefully constructed and especially made for spraying purposes. For use with Bordeaux mixture all the working parts coming in contact with the mixture should be made of brass. Iron is acted upon by Bordeaux mixture and is finally destroyed. Leather valves should be avoided for the same reason. A good-sized air chamber is also an essential feature in connection with the pump, as it helps to maintain a uniform pressure.

Two of the styles of pumps in common use are shown in the accompanying illustrations (figs. 31, 32).

Nozzles.

Being supplied with satisfactory power and pump, the next important feature of the outfit is the spray nozzle. A nozzle of the Vermorel or cyclone type (see fig. 33), when properly made, will give a fine mist-like spray and is to be preferred to other types. It is to be regretted that most of the nozzles in general use, whether of this form or some other, are not made with sufficient care. The nozzles should be made of brass and the inlet chamber and the opening through the cap should be very smoothly and accurately drilled.

The frequent use of a degorger will gradually wear the opening in the disk and make it irregular. For this reason interchangeable disks are desirable. These should be made of hardened brass, steel, or some other material which is neither attacked by the chemicals in the mixture nor easily injured by a degorger. Iron, zinc, and tin are worthless and should be carefully avoided. A poor nozzle wastes power and material and sprinkles the vines instead of spraying them, while the result of the work is not satisfactory. A properly made nozzle should give a fine mist-like spray with a minimum amount of pressure.

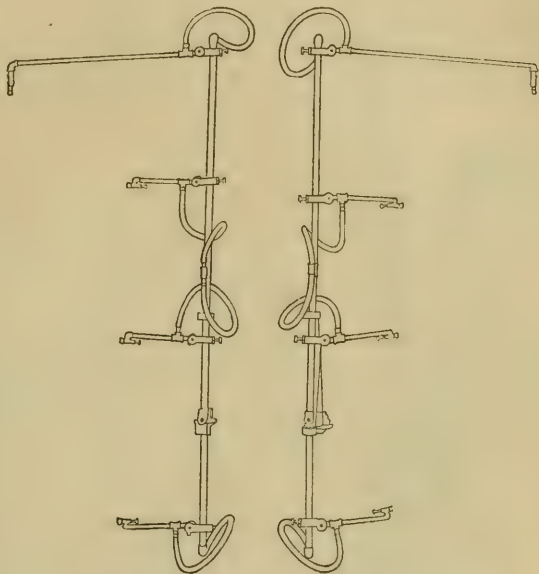


FIG. 30.—Adjustable rods and nozzles for vineyard spraying.

APPLICATION OF SPRAY MIXTURES.

Having a satisfactory outfit and the mixture properly prepared, there is still liability of failure unless the mixture is applied properly and at the proper times.

In spraying, the aim should be to cover as nearly as possible the entire surface of the vines, foliage, and fruit with the mixture, in order to destroy all the germs of the various parasites which may come in contact with the plant, and to destroy the insects which may feed upon the foliage, fruit, or buds.

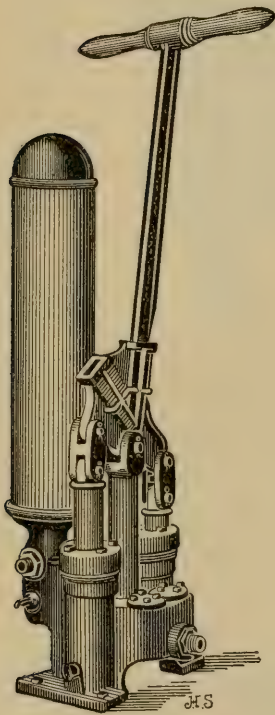


FIG. 31.—A large hand spray pump with double vertical cylinders for use with tank outfits.

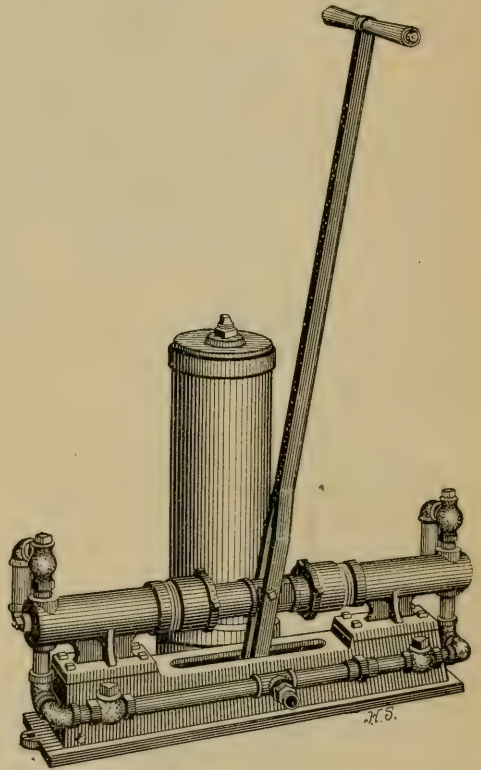


FIG. 32.—A large hand spray pump with double horizontal cylinders for use with tank outfits.

The accompanying illustrations (figs. 34 and 35) show two grape leaves to which Bordeaux mixture has been applied. Figure 34 shows a leaf properly sprayed. Figure 35 shows a leaf which has been sprinkled rather than sprayed. Too much of the mixture having been applied, it has run together in drops or fallen to the ground and been wasted. The leaf shown in figure 35 is, however, covered better than is generally the case in vineyard spraying. Thorough work is absolutely necessary if satisfactory results are to be secured. The nozzles should be carefully adjusted and directed, and should

also be watched to see that they do not clog. The rods with adjustable nozzles, such as shown in figure 30, have given best results. The team should be driven slowly and at the proper distance from the vines.

Time of application.

First application.—In case fungous diseases are causing serious loss, or the vineyard has not been sprayed before, a thorough application of the strong Bordeaux mixture mentioned (6-3-50 formula) should be made just before the buds open. For the grape-growing regions of New York, Pennsylvania, Ohio, and Michigan this will usually be about May 1. If injury from the grapevine flea-beetle is anticipated, an arsenical should be added to the mixture.

Second application.—This should be made just before the blossoms begin to open, which will be about the 1st of June for the States mentioned. The ordinary Bordeaux mixture (5-5-50 formula) should be used, and with an arsenical added the spray will be effective

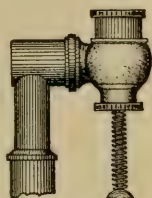


FIG. 33.—A vermorel spray nozzle.



FIG. 34.—A grape leaf properly sprayed, showing the surface covered with minute drops of the Bordeaux mixture.

against the grapevine flea-beetle, the rose-chaffer, grape curculio, and the first brood of the grape berry moth and the grape leaf-folder, respectively.

Third application.—This should be made as soon as the blossoms fall, using Bordeaux mixture as above and an arsenical to give

further protection against the insects mentioned and to poison the grape root-worm, the beetles of which are at this time just beginning to appear.

Fourth application.—This should be made within 10 days after the third application, using Bordeaux mixture as above and an arsenical. This and the preceding applications are especially important for the grape root-worm and the grape curculio, and will also afford further protection against the grape berry moth and the leaf-folder. For the insects first mentioned, it is very important that this application be delayed not longer than 10 days after the third.



FIG. 35.—A grape leaf improperly sprayed. The mixture has been sprinkled upon the leaf instead of being sprayed in a fine mist, and the surface is not evenly and properly covered.

Fifth application.—This should be made two weeks after the fourth, using the Burgundy mixture recommended, and no arsenical.

Sixth application.—This should be made about two weeks after the last application, using the Burgundy mixture only.

QUANTITY OF MIXTURE REQUIRED AND COST OF TREATMENT.

One hundred and twenty-five gallons of Bordeaux mixture is usually sufficient for a single application to an acre of vines of average size. Where the vines are large and the foliage dense, as much as 150 gallons may be necessary for a thorough application. It will be better to use too much of the mixture than too little. The cost for labor and material will vary from \$12 to \$15 per acre for six applications, including an arsenical poison for biting insects.

Issued May 10, 1907.

U. S. DEPARTMENT OF AGRICULTURE

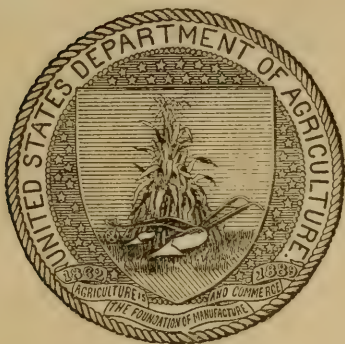
FARMERS' BULLETIN 290.

THE COTTON BOLLWORM:

A Summary of its Life History and Habits, with
Some Results of Investigations in 1905 and 1906.

BY

F. C. BISHOPP AND C. R. JONES,
Of the Bureau of Entomology.



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1907.

LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., February 26, 1907.

SIR: I have the honor to transmit herewith the manuscript of an account of the cotton bollworm, by F. C. Bishopp and C. R. Jones, of this Bureau, based on investigations conducted during the years 1905 and 1906, and to recommend its publication as a Farmers' Bulletin. The investigations are in continuation of those reported for the years 1903 and 1904 and published as Farmers' Bulletins 191 and 212 and Bulletin No. 50 of the Bureau of Entomology.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

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THE COTTON BOLLWORM.

INTRODUCTION.

The cotton bollworm (*Heliothis obsoleta* Fab.) is one of the oldest, most widely distributed, and most destructive of injurious insects. Its presence has long been felt by cotton planters throughout the South, and since about 1850 much attention has been devoted to it by entomologists.

The more important results of the earlier investigations conducted by the General Government were published in the Agricultural Reports of the Patent Office for 1854 and 1855, in Comstock's Report on Cotton Insects (1879), and in the Fourth Report of the United States Entomological Commission (1885). More recently Bulletins 24 and 29 (old series) of the Division of Entomology were issued in 1891 and 1893, respectively, as the result of supplementary investigations. In 1896 Dr. L. O. Howard gave a very comprehensive account of this species in Bulletin 33, Office of Experiment Stations, which was later revised and made available for general distribution as Farmers' Bulletin 47.

Since 1903 Congress has provided for a continuous investigation of the bollworm, on account of the serious injury inflicted by it in the western portion of the cotton belt during the past few years. The results of this investigation have been published in Farmers' Bulletins 191 (1904) and 212 (1905); and in Bulletin 50 (new series) of the Bureau of Entomology, in which Messrs. A. L. Quaintance and C. T. Brues give a very complete and concise account of the insect to date.

The dissemination of knowledge resulting from the general distribution of the several publications upon the life history, habits, and best means of control has not been entirely void of results. Nevertheless the great majority of planters have allowed its ravages to continue unchecked from year to year.

The crisis in cotton culture in Texas, brought about by the introduction and spread of the well-known cotton boll weevil, has awakened the planters to the importance of reducing injury by other cotton pests, in order to better their chances of securing a fair crop of cotton in spite of the presence of the boll weevil. Fortunately the methods found to be of most value in boll weevil control and those which are being largely adopted throughout the weevil-infested area of Texas are also of paramount importance in lessening bollworm ravages.

LIFE CYCLE.

There are four distinct stages in the life cycle of the bollworm, as is the case with all butterflies and moths—namely, the egg, larva, pupa, and adult.

The egg.—The eggs of the bollworm moths are deposited upon various plants and other objects, mainly, however, on the favorite food plants of the larvæ—corn, cotton, and less frequently on tomatoes and tobacco. They are quite small (about one-fiftieth of an inch in diameter), whitish objects, and may usually be seen in numbers on fresh corn silks or scattered about on the leaves of corn or upon the foliage and fruit of cotton, though in the latter instances they are less easily seen, owing to their pale color. The accompanying figure (fig. 1) shows the peculiar sculpturing of the egg surface as seen with the aid of a magnifier.

The number of eggs laid by a single moth varies from about 300 to nearly 3,000, with an average of about 1,100.

The temperature has a decided influence upon the length of the egg stage. It varies from two and one-half days during the summer months to eight days or even longer in the spring and fall.



FIG. 1.—Egg of bollworm; side and top views. Highly magnified (from Quaintance and Brues).

The larva.—The larva is the destructive stage of the insect and, of course, the one most generally noticed. When first hatched it is very small and is usually overlooked

until its injury to the plant upon which the egg was placed becomes severe enough to attract attention. This early period in the growth of the larva is practically the only time when it may be destroyed by the use of poisons. The period of growth of the larva is largely dependent upon temperature and the abundance of the food supply. The average length of this stage, in the summer months, is about sixteen days. During this short period the larva grows from a tiny object three-fiftieths of an inch in length to a stout worm $1\frac{1}{4}$ to $1\frac{1}{2}$ inches long. There is a decided variation in the color and markings of different individuals, nearly every gradation occurring from a pale green through rose color and brown to almost black.

The pupa.—When the larva has completed its growth it leaves its food plant, usually attempting to reach the ground by crawling; it then selects a suitable spot, usually within 2 feet of the base of the plant from which it crawled or fell, and burrows from 2 to 5 inches into the soil. A cell is then constructed running back to within from one-fourth to one-half an inch of the soil surface. This provision is made so that the moth may easily push off the cap of the cell and escape. When this cell is complete the larva molts its

skin at the bottom where the burrow is somewhat enlarged, and there enters the pupal or resting stage. The accompanying figure (fig. 2) illustrates the general form of a cell, with the pupa in its normal position.

As is the case with the egg and larval stages, the pupal stage is shortest during the summer months, usually lasting from twelve to sixteen days. The insect passes the winter as a pupa.

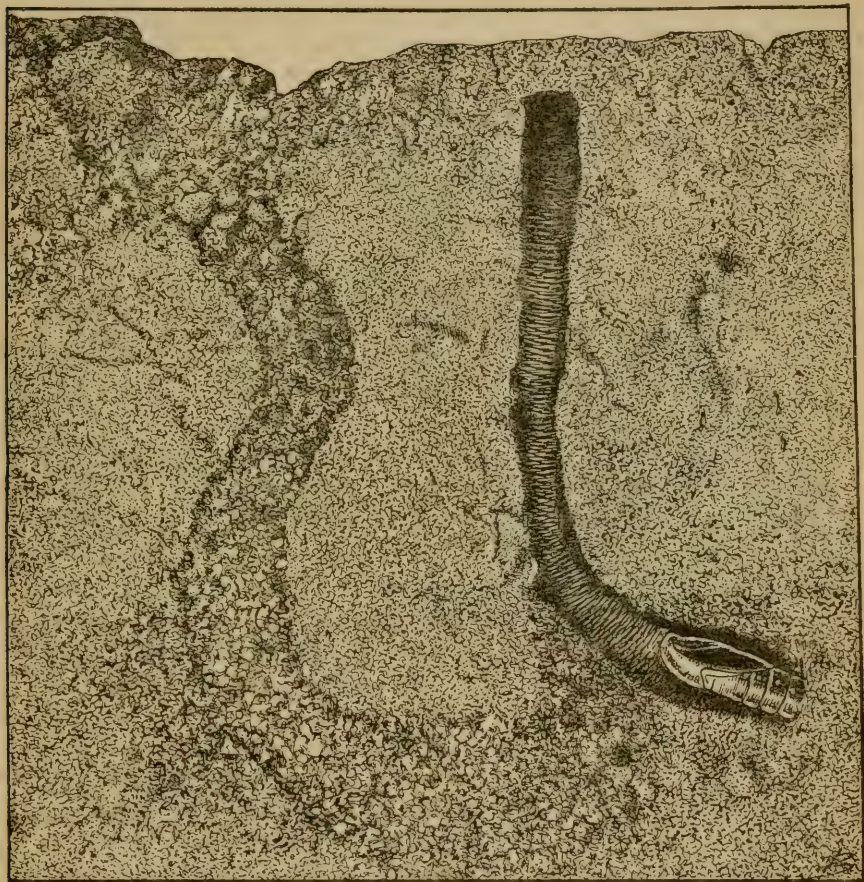


FIG. 2.—Vertical section through the soil, showing pupa of bollworm in its burrow.
(Copied from Quaintance and Brues.)

The fact that the adult is unable to make its escape when the pupa is buried under a few inches of dirt and that the pupa itself is killed by undue exposure immediately suggests the importance of fall and winter plowing so as to destroy these cells and thus expose the pupæ to the inclemencies of the winter weather and to destruction by birds and other enemies. This phase of the subject will be discussed later within these pages.

The pupa is nearly four-fifths of an inch long, shining, and of a reddish brown color.

The adult.—The bollworm moth, though very readily seen in corn or cotton fields, is recognized by but few planters as the parent of the bollworm. The accompanying figure (fig. 3) may aid in its recognition.

The moths vary considerably in color and markings, ranging from a dull olive green to nearly white. Some have conspicuous markings, while with others the markings are almost entirely absent. The body is about three-quarters of an inch long, and the wing expanse is about $1\frac{3}{8}$ inches.

During daytime the moths are seldom seen flying about, but late in the afternoon they come out from their hiding places among the foliage to seek food and deposit their eggs. It may be remarked here

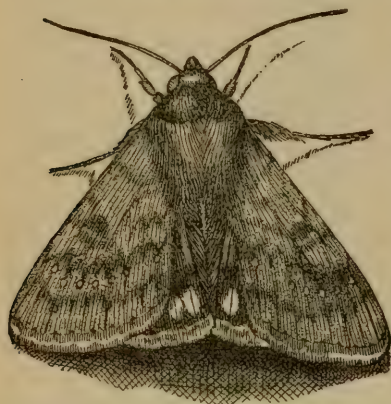


FIG. 3.—Bollworm moth in natural position, wings folded. About twice natural size (from Quaintance).

that the adults are capable of taking liquid food only. During the latter part of the summer this consists mainly of nectar secreted by the cotton plants. The moths are also very fond of the nectar secreted by cowpeas and when the latter are present the moths will leave the cotton fields to gather food from this source. It was found, from a large series of experiments conducted by Mr. A. A. Girault during the investigations of 1904, that the length of life of the moths depends largely upon the food supply. This also greatly

influences the number of eggs deposited. In the experiments referred to above, where no food whatever was given the moths the average length of life was five and one-fourth days, and where sirup was given each day it was twenty-three and two-thirds days.

Length of life cycle.—The life cycle, from the deposition of the egg to the emergence of the moth, is completed in about thirty days during the summer months.

FOOD PLANTS.

The bollworm is practically omnivorous. Its habit of very general feeding is among the difficulties experienced in attempting its control. The plants upon which the larvæ have been known to feed number about 70. The principal crops in the United States depredated upon

by this species are cotton, corn, tomatoes, tobacco, and various garden crops.

Various names have been applied to this insect according to the food plant or character of injury inflicted, the names "bud worm," "corn-ear worm," "tomato fruit-worm," etc., being variously applied. The term "sharpshooter," being very loosely used, is quite often applied to it. The exclusive use of the term "bollworm" should be encouraged to prevent confusion, regardless of the food plant upon which the insect is found.

SEASONAL HISTORY.

As has been stated, the winter is passed in the pupal stage in cells formed in the ground for that purpose. In the spring the moths emerge at a time varying considerably in different individuals and latitudes. In southern Texas, in the latitude of Victoria, the majority of the adults emerge early in April, and in northern Texas, in the latitude of Paris, about the middle of May. At Dallas, Tex., the date of the main emergence seems to be but little earlier than at Paris. Of course the time of the first as well as the maximum appearance of bollworm moths of the first generation depends largely upon the spring temperatures.

Soon after emergence in the spring the moths fly about to find suitable places for egg deposition, the great majority of them ovipositing upon the leaves of the young field corn, which is usually about 1 or 2 feet high at this time. Upon hatching, the young larvæ feed on the corn leaves, usually eating into the roll of tender leaves at the growing tip. This produces the characteristic shot-holed appearance in the leaves as they unfold.

By the time the second generation of moths appears, the corn is coming into silk and tassel and the eggs are deposited in numbers on the silks and tassels, as well as upon the leaves. This is the most destructive generation upon corn, the ears being largely attacked. The larvæ of this generation pupate about the time the ears begin to harden, so that when the moths of the third generation appear, about two weeks later, the corn ears are nearly all hard and consequently unfit for food for the young larvæ of the ensuing brood. Finding the corn hard and dry the moths are attracted to adjacent cotton fields, where most of the eggs are deposited; from these issues the destructive August generation of larvæ, which is the main source of injury to the cotton crop. Corn is by far the most preferred food of bollworms, hence if they can find late corn in the neighborhood the moths oviposit upon it rather than upon cotton.

Injury from the fourth generation is rarely serious, as the numbers of this generation are greatly reduced by parasites and unfavorable

weather conditions. The larvæ of this brood are often quite numerous on alfalfa and in a few instances do serious damage to very late cotton and corn. The larvæ of this generation usually form somewhat deeper cells than those occurring earlier in the season and for the most part they pass the winter as pupæ. However, a few moths may emerge, giving rise to the larvæ found in very late corn and gardens up to the time of heavy frosts. The number of annual generations varies in the cotton belt from four to six according to the latitude.

EXTENT OF INJURY.

Severe injury to cotton is confined largely to the western portion of the cotton belt. During the past few years Texas has suffered by far the greatest loss of any State from bollworm ravages. Yet the losses due to bollworm depredations in Louisiana, Indian Territory, Oklahoma, Mississippi, and Arkansas are by no means small.

A combination of circumstances in the western portion of the cotton-growing area has resulted in theoretically almost perfect conditions for bollworm development. The great increase in the cotton acreage during the past few years has been due largely to the development of lands west of the Mississippi on account of the westward tide of immigration. Central and northern Texas have afforded a vast practically unbroken area of cotton and the people in general have looked upon cotton and corn as the only crops to be successfully grown on a large scale. Hence the valuable practice of crop rotation has been sadly neglected. Insufficient cultivation, due in part to the tenant system so generally employed upon the large plantations in Texas, and to the planting of an acreage of cotton too great for the working force, and also the continued planting of run-down seed without regard to earliness, prolificacy, or quality of staple, have each lent their unfortunate influence in increasing the seriousness of the bollworm problem.

The average annual injury by the bollworm to the cotton crop of the United States is probably in the neighborhood of \$12,000,000.

INJURY, 1903-1906.

As has been pointed out, the extent of injury to cotton varies greatly from year to year. From a study of conditions during the past few years it appears that this depends mainly upon the relative earliness of the cotton crop, together with weather conditions. The amount of plowing done during the preceding fall and winter also exerts a decided influence upon the extent of injury.

During 1903 the cotton crop was exceptionally late; owing to adverse weather conditions during the preceding fall and winter

practically no plowing was done; the weather conditions during the latter part of the summer were favorable for bollworm increase; as a result, a year of severe and widespread depredations was experienced. Conditions in 1904 were almost the reverse and injury was much less general and less severe. The crop was planted very early, this being due in part to the fact that weather conditions during the fall and winter of 1903 permitted general plowing and preparations for planting. The winter plowing evidently resulted in the destruction of many pupæ, so that the moths emerging in the spring, as well as subsequent broods, were greatly lessened. On account of the decided earliness of the crop a considerable number of bolls were sufficiently mature to escape injury in the presence of an abundance of young bolls and squares.

During 1905 conditions were again favorable for bollworm depredations, and quite heavy losses were experienced in many counties in Texas, Indian Territory, and Louisiana. For some unknown reason little preparation was made in the fall of 1904 for planting during the following spring. The severe weather in February, followed by a wet spring, especially in northern Texas and Louisiana, resulted in general late planting throughout that section. Many heavy rains in the early summer, especially in northeastern Texas and western Louisiana, resulted in the very poor cultivation of most crops, and the complete abandonment of many fields.

While severe bollworm injury to cotton occurred over a considerable area of Texas and Indian Territory during the season of 1906, the total loss due to the pest was not so great as that inflicted in 1905.

Contrary to usual conditions the counties of extreme northeastern Texas did not suffer severe injury. The area of greatest damage extended throughout the two northern tiers of counties of Texas, from Lamar and Delta to Clay and Jack counties, and included the southwestern portion of Chickasaw Nation and the southern part of Choctaw Nation, Indian Territory. The loss to cotton growers in this area varied from 10 to 65 per cent of the crop, and in certain late-planted tracts the destruction of the crop was so complete as to render it unprofitable to even pick over the fields.

The precipitation in this section during July and August was considerably greater than normal and this condition was undoubtedly accountable, in part at least, for the greater loss occasioned by the bollworm.

In the following table a comparison is made of the cotton crop for each of the years 1903 to 1906, inclusive, in those eight counties of Texas in which exceptionally severe bollworm injury was inflicted during the year 1906.

The annual crop is given for these eight counties, taken collectively,

as also its percentage of the total crop of Texas for each year. The figures used in all cases are the number of bales ginned to December 13 of each year as given by the Census Bureau.

TABLE I.—Comparison of the cotton crop of eight counties in Texas for the years 1903–1906.

County.	Number of bales, 1906.	Number of bales, 1905.	Number of bales, 1904.	Number of bales, 1903.
Collin.....	46,902	31,035	85,128	55,995
Cooke.....	17,018	18,910	23,048	17,887
Denton.....	25,176	26,066	46,456	31,778
Fannin.....	57,241	35,887	81,031	40,314
Grayson.....	31,063	31,807	81,878	48,770
Hunt.....	54,186	27,359	66,658	45,453
Montague.....	30,568	30,069	36,270	27,370
Wise.....	32,304	32,320	40,181	30,014
Total for eight counties given above.....	294,458	233,453	465,650	297,581
Total for Texas.....	3,486,365	2,172,881	2,953,067	2,171,068
Percentage of Texas crop grown in eight counties given above.....	8.44	10.74	15.77	13.71

It is notable that the crop produced in these eight counties of Texas in 1906 constitutes but 8.44 per cent of the total crop of the State, while in 1904—a year of comparatively slight bollworm injury—the crop of this area was 15.77 per cent of the State's production. In 1903, a year of unusually heavy bollworm injury, the area under discussion produced 13.71 per cent of the crop of Texas. This comparatively large percentage may be explained by the fact that severe bollworm injury was more general during that year, and less severe in this section than in those counties in the extreme northeastern part of the State. The reduction of the total crop of Texas by the ravages of the boll weevil in 1903 also caused the percentage of the crop grown in these northern counties to appear larger, while in 1906 the crop produced in other parts of the State was exceptionally large, thus correspondingly reducing the percentage of the crop produced in this area of heavy bollworm damage.

The accompanying diagram (fig. 4) shows the approximate area of bollworm injury to cotton in Texas, Indian Territory, and Oklahoma during 1906.

MEANS OF CONTROL.

The control of the bollworm as compared with many insects presents unusual difficulties. However, as in the case of most insects, a careful study of its life history and habits has revealed certain facts which, if taken advantage of, render control quite certain.

CULTURAL METHODS.

Some planters seem to have gained the idea that when cultural methods are spoken of reference is being made to some complicated

and impractical system of cotton growing. This erroneous idea has been largely dispelled by the distribution of publications upon this subject and by the demonstration work conducted by the Bureau of Entomology during the boll weevil and bollworm investigations.

The influence of unscientific methods of farming upon insect depredations has been repeatedly shown. In the case of the bollworm, as with many other insects, it has been found from experiments con-

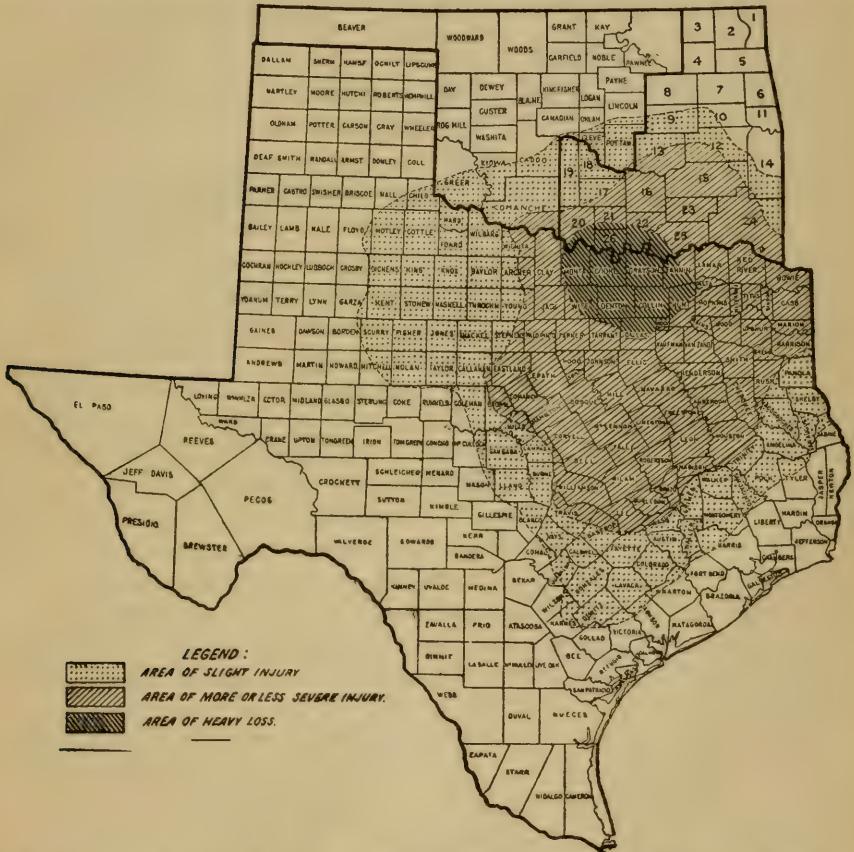


FIG. 4.—Area of bollworm injury in Texas, Indian Territory, and Oklahoma in 1906.

ducted during the past few years that much success attends the adoption of improved farm methods, such as:

- (1) The planting of early maturing varieties.
- (2) Early planting in the spring.
- (3) The use of fertilizers.
- (4) Early and thorough cultivation.
- (5) The plowing in the fall or winter of all land likely to contain hibernating pupæ.

In short, any farm operation which will tend to hasten fruit production and its maturity is of value. Numerous observations indicate that bolls which are three-quarters grown or more by August 1 are practically exempt from bollworm injury; in fact, it is admitted by all that early cotton is much less subjected to injury than late cotton. This is due to the preference of bollworms for the more succulent young plants and fruit. As has been stated, few bollworms attack cotton until the appearance of the third generation, about August 1; the importance of having fruit production well advanced at this date is therefore quite evident.

The planting of cotton early in the spring is practically the only operation, valuable in reducing bollworm injury, which has received general attention by planters. The advantage gained by this desirable practice is often offset, to a great extent, by the use of "run-down" seed. Oftentimes planters fully appreciate the advisability of early planting, but are unable to carry it out owing to the fact that the land has not been prepared during the fall and winter. Many delay their planting in the spring so as to be sure that all danger from frost is past. On the whole, the gains made by early planting year after year entirely eclipse the occasional losses from late frosts.

It has been amply proved that the use of fertilizers on many Texas, Louisiana, and Indian Territory soils aids greatly in securing early maturity of cotton, as well as in increasing the yield.

The allowance of ample room between the rows and the practice of early chopping so as to encourage branching close to the ground have been found valuable in increasing early square production, and the consequent early maturity of bolls. Early and frequent cultivation should also be practiced to aid in the conservation of the moisture necessary to dissolve plant food in the soil and thus hasten the growth.

In all cases the crop should be gathered as expeditiously as possible, so as to allow the land to be thoroughly plowed during the fall and winter. As has been stated, the destruction of the hibernating pupæ may be largely accomplished by this practice and, in consequence, the succeeding generations of bollworms greatly reduced. Winter preparation of the land is, of course, a requisite for early planting as well.

ARSENICAL POISONS.

In order that a thorough understanding may be had of the use of arsenical poisons against bollworms, it will be necessary to outline briefly the habits of the adults and larvæ in cotton fields.

From numerous observations made upon the egg-laying habits of the moths during the past three years it has been determined

that from 60 to 78 per cent of the eggs deposited in cotton fields are placed elsewhere than on the squares and flowers.

Immediately upon hatching the young larvæ usually devour the eggshell from which it emerged. It then begins a restless search for food, wandering aimlessly about, and now and then eating a tiny portion of the epidermis of the plant. Often these actions are continued for hours, many of the delicate larvæ perishing before suitable food is found. The minute larvæ are unable to enter any but the most tender portions of the plant; consequently those hatching from the large percentage of eggs which are not placed on the tender squares, flowers, and small bolls crawl about and feed to a greater or less extent upon the surface of the plant until such portions are found.

A number of observations were made during August, 1905, upon larvæ hatching from eggs deposited on squares and flowers. The six larvæ under observation averaged about forty minutes in crawling about and feeding before the squares or flowers were entered—an ample time for them to have eaten sufficient poison to have destroyed them had these portions of the plant been thoroughly dusted with Paris green. Hence it appears, from various observations, that it would be theoretically possible to destroy about 90 per cent of the larvæ at the time of hatching, if the plants were kept continuously and thoroughly covered with Paris green. The impossibility of maintaining poison continuously upon all parts of the plants during the entire period of egg hatching is obvious. However, practical tests of poisoning cotton (see pp. 25-27) indicate that satisfactory results may be obtained by making from 1 to 3 applications of Paris green or other arsenical poison at the proper time.

No arbitrary date for the application of poison may be given on account of the variability of the time at which the larvæ begin to hatch in destructive numbers in different localities and seasons. Moths are seldom seen in cotton fields until the third generation appears, which is usually from July 20 to August 5. When moths in large numbers are seen flying about the fields in the evening it may be taken for granted that oviposition is taking place and the poison should be applied within three or four days.

As regards the dusting and spraying methods, the former is usually more practicable, owing to the difficulty often experienced in securing water in proximity to the fields and the greater time required in applying poison in liquid form.

The bag and pole method of application is fairly efficient and obviates the purchase of machinery. Geared machinery may be secured to apply poison either in the dust or spray form. The expense of

purchasing such machinery may be reduced by two or three planters buying one machine for their common use. By the use of geared machinery from 20 to 30 acres of cotton may be dusted in the few hours suitable for the work. In order to secure good results the plants should be dusted while still wet from dew or a light shower, as the moisture aids in retaining the fine particles of poison upon the foliage.

Three pounds of Paris green should be applied per acre and where large machines are used economy may be practiced by mixing the poison with from three to four times the amount of cheap flour or fine, air-slaked lime. In spraying, the poison should be used at the rate of 1 pound to 50 gallons of water. Owing to the variability in strength of poisons only reliable brands should be purchased.

The decided prejudice on the part of many planters and pickers against the application of poison is entirely unfounded, for no danger attends its proper use either in the application or in picking cotton in fields which have been treated.

TRAP CROPS.

As has been stated, corn is the preferred food of bollworm larvæ and nectar secreted by cowpeas is very attractive to the moths. From a consideration of these facts it is perfectly natural to conclude that by proper manipulation these may be made to form a trap for the bollworm and thus protect cotton or other crops from injury.

The best results may be secured by leaving several unplanted strips, from 60 to 80 feet wide, across the fields at the time of planting cotton. These strips should later be planted to corn and cowpeas in alternate rows about 3 feet apart at a time which will permit of the corn being in silk and tassel and the peas in bloom by August 1, the approximate date of the emergence of the majority of third generation moths. The early corn being then about ripe the moths are immediately attracted to the trap rows. The cowpeas afford food and hiding places for the moths and corn is the favorite plant for oviposition; the moths are therefore content to remain in the trap rows and here their eggs are concentrated, thus leaving the adjacent cotton practically free.

The accompanying table gives some idea of the number of eggs kept from surrounding cotton fields by the employment of a small area of June corn as a trap crop. These observations were made during 1905 at Ardmore, Ind. T., on a small area of corn which was in prime silking condition on August 1. At the time of the first examination the corn was in full silk and when the second examination was made the silks were largely dry and some corn in roasting ears. The figures show the average number of eggs per plant and

the average number on various portions of the plant; also the average number of larvæ per plant and their approximate sizes.

TABLE II.—Average number of bollworm eggs and larvæ on corn trap crop.

Date of examination.	Number of plants examined.	Average number of eggs per plant.					Average number of larvæ per plant.					
		On entire plant.	On leaves.	On sheath.	On tassel.	On silk.	All sizes.	Less than one-fourth grown.	One-fourth grown.	One-half grown.	Three-fourths grown.	Full grown.
August 1	10	414.3	103.6	42.2	71.7	196.8	3.4	2.7	.7	.....	.....	.....
18	5	168	58	11	24.4	74.6	22.3	11.8	5.4	3.2	1.8	.1

Viewing the trap-crop idea superficially it might appear that the increase of bollworms would be favored by supplying their favorite food. This, however, is not the case. The concentration of the eggs upon the corn results in their destruction in large numbers by parasites and predaceous enemies which are attracted by the abundance of food and favorable breeding places furnished them in the form of bollworm eggs and larvæ. It is seldom that more than 1 or 2 of the 15 to 30 larvæ which usually hatch in the fresh silk of an ear of corn ever attain full growth on account of their cannibalistic habits.

The mistake of planting belts of corn through or around a cotton field at the usual time of planting corn in the spring is of quite common occurrence. Instead of this acting as a trap, as is desired, it is really detrimental, as the corn furnishes a favorable breeding place for the larvæ during the early summer and becomes hard about the 1st of August, thus forcing the moths of the third generation to seek other places for oviposition.

With favorable weather conditions and fair cultivation corn planted the last of May or 1st of June will be in silk and tassel by August 1. Cowpeas planted about ten days later will be in full bloom about that date. Mexican June corn is usually preferable for late planting, owing to its larger root system and consequent greater ability to withstand drought.

The trap-crop system will give best results if generally adopted by the farmers in each locality. On large plantations the planting of small areas of corn here and there in the fields is practicable. Such early crops as potatoes, oats, or wheat may be followed by corn and cowpeas with practically the same results.

The corn may be harvested in the usual way, and the peas either harvested or plowed under. Mention should be made of the benefit exerted upon the soil by the growing of cowpeas or other plants of this class.

FIELD WORK, 1905-1906.

Laboratory investigations of the bollworm, such as the breeding of parasites, the studying of predaceous insect enemies, etc., were carried on during the year 1905. Attention was devoted mainly, however, to field experiments and demonstrative work. As the investigating force was limited to the writers, it was found impossible at times, when the work was most pressing, to devote such personal attention to some of the experiments as was desired. Only a portion of the writers' time could be devoted to bollworm work during the year 1906, and for this reason laboratory investigations were entirely eliminated.

The bollworm investigations during the last three years have been confined principally to those portions of northern Texas and southern Indian Territory which have suffered most in recent years from bollworm depredations. The endeavor has been to locate the experiments, as far as possible, in territory not seriously infested with boll weevils, and thus avoid complications from this source in the results.

In general, the field work has been continued along lines similar to those followed in 1903 and 1904, some results of which were published in Farmers' Bulletins 191 and 212.

The following is a list of the experimental and demonstration farms established:

Experimental farms used in bollworm investigations.

1905.

Location.	Plantation of—	Number of acres.
New Boston, Tex.	H. B. Eubank	48
Avery, Tex.	P. B. Gibbons	40
Quinlan, Tex.	R. W. Hodge	16
Do.	Joe H. Smith	24
Do.	W. B. Green	8
Do.	G. H. Vining	12
Do.	W. F. Addington	10
Do.	D. F. Borden	10
Do.	W. E. Smith	10
Do.	W. A. Wallace	10
Do.	W. Higden	10
Greenville, Tex.	Capt. J. F. Nichols	40
Rosser, Tex.	Geo. F. Stribbling	40
Ardmore, Ind. T.	W. P. Poland	20
Do.	S. A. Brown	40
Atoka, Ind. T.	John Wilson	12
Mound, La.	Col. F. L. Maxwell	55

1906.

Denton, Tex.	S. W. Kanady	24
Mineola, Tex.	J. W. Bogan	10
New Boston, Tex.	J. N. Glass	48
Wolfe City, Tex.	C. E. Keithly	48
Do.	J. C. Clement	28
Mound, La.	Col. F. L. Maxwell	55
Ardmore, Ind. T.	D. L. King	40

During 1905, in addition to the 405 acres mentioned, about 50 acres were used in 12 farms near Clarksville, Tex., in a cooperative test of the corn trap-crop system, and several small areas were used in cooperative work in other localities.

Upon these experimental farms an endeavor was made to demonstrate the value of the several remedial measures outlined in the preceding pages, under "Means of Control."

In all of the experiments conducted in 1905 the results, as shown by final yields, were supplemented by observations throughout the season upon the relative earliness of and comparative bollworm injury to the plats receiving various treatments. The results of these observations conform closely with the final yields and strongly emphasize the value of improved methods in protecting cotton from bollworm injury. These observations include cotton grown on the principal types of soil of northern Texas.

At the time of examination the injury to late planted cotton and to cotton raised from degenerate seed varied from 12 to 49 per cent, and to early planted cotton and cotton grown from improved seed the injury varied from 1 to 23 per cent.

To illustrate the decided preference of the bollworm for the less mature fruit, of a total of 24,292 squares and bolls examined in several localities, those one-half grown or less numbered 20,789, of which number 20.4 per cent were injured; the bolls over one-half grown numbered 3,504, with 7.2 per cent injured. The contrast between the percentages of injury would have been still greater had the examinations been made two weeks earlier, as a considerable number of the injured squares and bolls had fallen and were buried by cultivation, while the majority of the more mature fruit was retained by the plant even though badly injured.

ARDMORE FARM.

The experimental area on the farm of Mr. S. A. Brown was located on a typical sandy soil of the cross timber region and consisted of ten 4-acre plats.

The experiment consisted of comparing the King and Rowden varieties now becoming so generally adopted in the bollweevil and bollworm districts of Texas with the much later big-boll sorts from gin-run seed. The effect of commercial fertilizers upon the early maturity and total cotton production was also studied. Three standard commercial fertilizers were used in the experiment: (1) A complete fertilizer, showing by analysis 8 per cent available phosphoric acid, 2 per cent potash, and 2 per cent nitrogen; (2) a compound of acid phosphate and potash without nitrogen, the analysis of which showed 10 per cent available phosphoric acid and 4 per cent potash;

(3) acid phosphate alone, showing by analysis 14 per cent available phosphoric acid.

The following table shows the treatment given and the yield from the several plats, together with the increased yield from the use of fertilizers and improved seed, as compared with the yield of cotton from ordinary gin seed.

TABLE III.—*Treatment of and results from plats on bollworm experiment farm of U. S. Department of Agriculture, Ardmore, Ind. T., 1905.*

Plat No.	Variety of cotton.	Fertilizer, and quantity used per acre.	Date of planting.	Number of times cultivated.	Number of times hoed	Yield per acre in pounds of seed cotton.	Increase per acre in pounds of seed cotton as compared with Plat VII.	Value of increase with seed cotton at 33 cents per pound.	Cost of fertilizer per acre.	Net gain per acre.
I	King.....	C. B. G., ^a 300 pounds.	Apr. 28	4	3	1,082.75	712.75	\$23.25	\$3.45	\$20.07
II	Rowden.....	do.....	Apr. 29	4	3	1,003.75	633.75	20.91	3.45	17.46
III	King.....	Unfertilized.....	May 1	4	3	810.75	440.75	14.54	.....	14.54
IV	Rowden.....	R. P. C., ^b 300 pounds.	do.....	4	3	837.50	467.50	15.42	3.23	12.19
V	King.....	do.....	May 2	4	3	834.50	464.50	15.33	3.23	12.10
VII	Big boll (variety unknown).	Unfertilized.....	May 3	4	3	370.00	.....	.....	.....	.....
VIII	King.....	R. A. P., ^c 300 pounds.	May 4	4	3	917.00	547.00	18.05	2.85	15.20
IX	Rowden.....	Unfertilized.....	do.....	4	3	430.25	60.25	1.99	.....	1.99
X	do.....	R. A. P., 300 pounds.	May 5	4	3	749.75	379.75	12.53	2.85	9.68

^aC. B. G.—A commercial cotton boll guano; analysis—available phosphoric acid, 8 per cent; potash, 2 per cent; nitrogen, 2 per cent.

^bR. P. C.—A commercial potash compound; analysis—available phosphoric acid, 10 per cent; potash, 4 per cent.

^cR. A. P.—A commercial phosphoric acid; analysis—available phosphoric acid, 14 per cent.

Table IV, which follows, shows the comparative earliness of fruit maturity on the several plats. The amount of seed cotton picked from each plat during each month is followed by the total amount picked from said plat to the end of that month.

TABLE IV.—*Comparative earliness of fruit maturity on plats on bollworm experiment farm of U. S. Department of Agriculture at Ardmore, Ind. T., 1905.*

Plat No.	Total pounds of seed cotton picked.								
	During August.	During September.	To September 30.	During October.	To October 31.	During November.	To November 30.	During December.	To December 31.
I	613	1,834	2,447	1,223	3,670	661	4,331	0	4,331
II	568	622	1,190	1,021	2,211	1,502	3,713	300	4,013
III	247	1,086	1,333	678	2,011	952	2,963	280	3,243
IV	0	916	916	821	1,737	1,303	3,040	310	3,350
V	565	1,358	1,923	821	2,744	274	3,018	320	3,338
VII	0	302	302	0	302	0	302	1,178	1,480
VIII	191	1,127	1,318	1,329	2,647	0	2,647	1,021	3,668
IX	0	303	303	533	836	0	836	885	1,721
X	0	786	786	655	1,441	836	2,277	722	2,999

From a study of the table several important points immediately present themselves. The decided earliness of fruit production upon the King plats is very noticeable. During August all of the King plats had opened a sufficient number of bolls to be picked over, while but one of the Rowden plats could be picked. The uniform earliness of the fertilized as compared with the unfertilized plats is also noticeable; for instance, on September 30 Plat I—King seed, fertilized—had produced 2,447 pounds seed cotton, while on the same date Plat III—King seed, unfertilized—had produced but 1,333 pounds. Comparing results from the use of the three different fertilizers, plats upon which the complete fertilizer was applied excelled both in earliness and total production. The average yield per acre in pounds of seed cotton was 1,043.25, 836, and 833.37 upon the plats fertilized with complete fertilizer, potash compound, and acid phosphate, respectively. The contrast in earliness and total yield in the case of Plat VIII, planted with unimproved seed and unfertilized, and the various other plats is so marked as to need no special mention.

NEW BOSTON FARMS.

Twelve plats of 4 acres each were used in the experiment conducted upon the plantation of Mr. H. B. Eubank during 1905. The soil upon which the experimental farm was located consists of a sandy loam, with a red clay admixture.

The exceedingly adverse weather conditions during the spring and early summer greatly handicapped the experiment, and resulted in a smaller yield than was anticipated; however, all circumstances considered, the results were very satisfactory.

The experiment consisted of a fertilizer test in which King, Rowden, and gin seed were used. The best results, both in earliness and total production, were obtained by using King seed, fertilized with 300 pounds of cotton-seed meal and 100 pounds of acid phosphate per acre. Almost as good returns were secured by using King seed fertilized with 100 pounds per acre of each of the following: Acid phosphate, German kainit, and nitrate of soda.

During the past season Mr. J. N. Glass conducted a similar experiment upon his plantation, which is located in the deep sandy land region south of New Boston. Owing to the comparative freedom from bollworm injury the cultural methods employed were not put to a severe test, hence the results as shown by the total yield from plats where fertilizers and improved seed were used and early planting and thorough cultivation were practiced can not be satisfactorily compared with the yields from unfertilized plats planted to gin seed

and receiving only ordinary care. In all cases there was a ready response to the application of complete fertilizers, both in earliness and increased production.

SUMMARY REMARKS CONCERNING THE USE OF FERTILIZERS.

From three or even several years of tests with fertilizers the writers would be entirely unwarranted in making other than certain general statements regarding their use. The decided variability in the soil constituents, even upon the same character of land, and the variation in weather conditions during different seasons render specific recommendations inadvisable.

Many of the Texas soils have been found to be benefited by phosphoric acid. As the chief object of these experiments has been to increase early fruit production, and as acid phosphate influences and hastens fruiting, the general plan has been to supply an abundance of this element along with the other elements in which the various soils are supposed to be deficient.

The question is still open as to whether the general use of fertilizers upon the rich bottom lands and strong, black waxy lands of northern Texas will prove of value. However, there seems to be no doubt that the application of fertilizing elements to many of the soils of northern Texas and Indian Territory will increase the earliness and prolificacy of cotton. The experiments at Ardmore, Ind. T., and New Boston, Tex., indicate that the use of complete fertilizers with a large percentage of phosphoric acid will give best results upon the sandy loam soils of those types. Experiments conducted upon the gray or mixed soils, as in the case of the plats on the farms of Mr. C. E. Keithly at Wolfe City, Tex., and Mr. S. W. Kanady at Denton, Tex., indicate that soils of this type respond freely to the application of acid phosphate. The addition of a small percentage of potash to an acid phosphate fertilizer seems also to give beneficial results. In general, fertilizers containing large percentages of nitrogen should be avoided, as they tend to produce a large and succulent growth of stalk and foliage which favors bollworm as well as bollweevil depredations. In order to secure the best results from the use of fertilizers it is necessary that the soil be kept in good physical condition.

It is to be hoped that the data obtained during the investigations of the past three years may serve as a basis for experimentation on the part of planters in various localities to determine which of the three principal elements of plant food—namely, phosphoric acid, potash, and nitrogen—and what proportions and amounts of each, will give the best results on their respective soils.

INJURY TO FIELD CORN.

The close relation between the depredations of the bollworm upon corn and cotton has necessitated a careful study of the insect in the former as well as in the latter crop. The characteristic injury to corn has been described in the preceding pages. Although bollworm injury to cotton greatly eclipses that to corn, the loss occasioned by its presence each year in probably more than 75 per cent of the corn ears and by the additional damage resulting from ferments, molds, and rain admitted through the exit holes of the larvæ is considerable.

Injury to young corn by the first brood of bollworms is seldom serious. A notable exception, however, is presented in the case of extremely severe injury inflicted upon young corn by this brood at Victoria, Tex., during the spring of 1905. Mr. W. W. Yothers, of the Bureau of Entomology, investigated this outbreak quite thoroughly during the latter part of May. It was found that severe injury had been inflicted over quite an extended area, necessitating the replanting of a considerable portion of the corn acreage to June corn or cotton. It was estimated by Mr. Yothers and others that the total yield in the vicinity of Victoria would be reduced fully 40 per cent on account of bollworm injury. Severe injury to corn was reported also in Shackelford County, Tex., but its extent was not definitely ascertained.

In 1905 numerous observations in northern Texas and Indian Territory showed the number of eggs and larvæ to be comparatively few upon corn until about July 1. After this date, however, from 90 to 100 per cent of the corn ears were found to be infested. No serious injury to corn was reported in 1906, but observations showed that practically complete infestation of corn ears was attained during the latter part of the summer.

The chief means of reducing bollworm injury to corn is by thoroughly breaking, during the fall and winter, all land likely to contain hibernating pupæ, a procedure which the writers have stated to be an important part of the cultural system in reducing bollworm injury to cotton. The practice of having children and plow hands destroy all larvæ noticed in the buds of young corn plants is commendable.

RESULTS OF POISON EXPERIMENTS.

During 1904 poison experiments were conducted at Ladonia, Paris, and Cooper, Tex. At Ladonia and Paris the experiments were conducted directly by the writers, while at Cooper the work was carried out by Mr. N. P. Robertson, of that place. The dusting method was used exclusively. The Paris green was mixed with fine, air-slaked lime at the rate of 1 pound of Paris green to 4 pounds of lime, and the

mixture applied at the rate of 15 pounds per acre. The general plan adopted in all the poison experiments was to select two areas of from 3 to 10 acres each upon which the cotton was as uniform as possible, then to apply poison to one, leaving the other as a check.

At Ladonia and Paris 24 acres were poisoned, an equal acreage being left unpoisoned as a check. A hand blower, mounted on a wagon with wheels sufficiently far apart to include between them two cotton rows, was used in these experiments, while at Cooper a geared blower was employed. Desirable results have attended the application of poison in practically every instance. The unfavorable results shown in a few cases were attributable to unevenness of stand or to a too late application of the poison.

The results of the poison experiments at Cooper are given below:

TABLE V.—*Results of experiments of the U. S. Department of Agriculture in poisoning the bollworm, at Cooper, Tex.*

On plantation of—	Number of applications.	When applied.	Area poisoned.	Area unpoisoned—check.	Yield of seed cotton from poisoned area.	Yield of seed cotton from unpoisoned area.	Gain of seed cotton per acre where poison was applied.	Value of gain at \$0.0325 per pound.	Cost per acre of poison mixture.	Cost per acre of mixing and applying poison.	Net gain per acre where poison was used.
			Acres.	Acres.	Lbs.	Lbs.	Lbs.				
S. Robertson	1	Aug. 15	2½	2½	2,508	1,892	246.5	\$8.00	\$0.61	\$0.60	\$6.79
T. C. Hunter	1	Aug. 9	5½	5½	6,325	5,750	100.0	3.25	0.61	0.60	2.04
Fred Johnson	1	Aug. 11	5	5	3,954	3,546	81.6	2.65	0.61	0.60	1.44
N. P. Robertson	2	Aug. 12 Aug. 18	5½	5½	5,922	3,609	420.0	13.66	1.22	1.20	11.24

The above figures show a weighted net gain of \$5.21 per acre upon the four poisoned areas, as compared with similar adjoining areas which were not poisoned.

The marked gain upon the plat receiving two applications was probably not due so much to its having received two applications as to the exceptionally favorable conditions attending the poisoning. The two fields showing the greatest gain per acre were smooth, so as to admit of the easy manipulation of the large machine over the entire area, while the others were more or less rough; the wind was also favorable when the former fields were treated. A slight shower preceded the second application upon the area on Mr. N. P. Robertson's farm, thus causing the poison to adhere well to the plants.

During 1905, at Quinlan, Tex., about 50 acres were used in poison experiments. In general, the results of these experiments were satisfactory. Apparently no advantage was gained by making a second

application between August 17 and 20, the first having been made between August 1 and 5.

On August 24 counts were made to determine the percentage of injury to cotton on the poisoned and unpoisoned areas on the farms of Messrs. W. A. Wallace and W. Higden. Ten typical plants were chosen in each of the poisoned and unpoisoned areas, and all fruit upon the plants and ground beneath them carefully examined. On Mr. Wallace's farm the plants on the unpoisoned plat showed that over 16 per cent of the entire fruit was injured, while only 10 per cent of fruit on plants on the poisoned plat showed injury. On Mr. Higden's farm 15 per cent of the fruit of the plants on the unpoisoned plat was found to be injured, while but 9 per cent was injured on the poisoned plat.

TRAP CROP EXPERIMENTS.

In view of the fact that the greatest benefit from the use of June corn as a trap crop will come from its general planting throughout a neighborhood, an endeavor was made during the spring of 1905 to arouse general interest in the trap-crop system among the farmers in the vicinity of Clarksville, Tex. Nearly every season bollworms are more or less destructive in this locality, hence it was deemed a desirable place for a test of this kind.

Arrangements were made with each of several planters just north of Clarksville to plant from 3 to 6 acres of June corn and cowpeas. The total area thus arranged for in the experiment was about 50 acres.

Unfortunately the abnormally heavy rains during June and early July rendered cultivation of the corn impossible. In several instances the crop was entirely killed out by the excessive rains and weed growth.

There is no way of measuring the value of a trap crop in pounds of seed cotton, as it is impossible to arrange a check plat of cotton where conditions are identical without having the plats adjacent, and in this case equal protection is afforded both of the cotton areas. Although the experiment was greatly handicapped by the above-mentioned weather conditions, numerous observations during August and September showed that the adjacent cotton was being protected to a considerable extent by the deposition of a large number of bollworm eggs on the trap corn.

At Quinlan, Tex., about 30 acres were utilized in a similar experiment, with apparently good results. In some instances, in addition to the protection afforded the adjacent cotton, a large yield of corn was obtained from the trap areas.

LOCAL EXTERMINATION.

Many insects increase with amazing rapidity from the comparatively few individuals which pass the winter successfully to the countless thousands at the close of summer. The bollworm offers a good example of this, although the increase in its case is not so striking as with some other insects.

It has been estimated by Messrs. Quaintance and Brues, from observations made during 1904, that in the third generation the larvæ resulting from one female emerging the previous spring would number 21,175; or one larva of the first generation will give rise to 683 descendants in August—a sufficient number to completely ruin 78 large cotton plants. In making these calculations due allowance was made for destruction in the different stages by various natural agencies. From these figures the importance of destroying the larvæ of the early generations is very apparent.

Experiments conducted at Quinlan, Tex., and Atoka, Ind. T., during 1905 indicate that in isolated localities almost complete freedom from bollworms in cotton may be secured by destroying the larvæ of the first and second generations in all adjacent cornfields.

Various mechanical devices have been suggested for use in destroying larvæ in corn ears. The writers have given the subject some attention, but have been unable to devise any satisfactory scheme for killing the larvæ without opening the ears by hand. When mechanical devices are used the ears are often greatly damaged and in many instances the larvæ escape.

In the experiments conducted very few larvæ of the first generation were seen in the young corn, and the fields were not carefully gone over at that time; however, nearly every ear was infested by the second brood, as is shown in the accompanying table. In case of the *Mineola* record, ears upon which eggs were deposited were not included in the number of those infested. Had these been included with the number of infested ears, as should have been done, the infestation would have reached about 92 per cent.

TABLE VI.—*Bollworm larvæ in corn and cost of extermination.*

Locality.	Date of extermination.	Total ears examined.	Percentage of ears infested.	Total larvæ destroyed.	Cost per acre of extermination.
Quinlan, Tex.	July 25, 1905	8,615	96.1	8,706	\$4.40
Atoka, Ind. T.	July 29, 1905	8,279	95.7	10,924	3.54
Mineola, Tex.	July 20, 1906	14,748	74.4	11,039	2.20

At Quinlan the larvæ were extracted from the ears on about 3 acres of corn and at Atoka from about $2\frac{1}{2}$ acres. About $7\frac{1}{2}$ acres of

corn were thus treated at Mineola. The stand, however, was poor, and therefore the number of ears per acre was comparatively small. In these experiments each ear was opened sufficiently at the tip to admit of the destruction of all larvæ with the fingers. The cost of the work was increased about one-third on account of the making of a complete record of the number of eggs upon the fresh silks and the number and approximate size of all larvæ.

For several reasons it is safe to say that the practice of destroying larvæ of the early generations in corn, however important, will never be generally adopted. In the first place it would be impossible to get concerted action in work of this kind, where immediate results can not be seen. The question of securing efficient labor at the time the work should be done, though difficult, would be no more so than that of finding time to go over large areas of corn. The practice of opening the corn ears might also be objectionable in some cases, as it would increase the danger of loss from decay and mildew during rainy seasons. The husks should be closed after removing the larvæ, so as to protect the ears from injury by birds.

At present it seems that the plan of extermination can only be profitably adopted in isolated localities and where the corn acreage is small as compared with the acreage of cotton thus protected.

Owing to the fact that the moths fly freely, entire protection to cotton can not be insured even though all larvæ are destroyed in adjoining cornfields—if there are such in the immediate neighborhood. However, where some barrier exists, such as timber or a large field of grain—the former especially—between neighboring cornfields and the area for which protection is being sought, there is little danger that moths will find their way in numbers to the cotton.

THE MORE IMPORTANT NATURAL FACTORS IN BOLLWORM CONTROL.

The feeding habits of the bollworm larvæ afford them much protection from various natural enemies. The mortality from these sources is therefore much greater in the egg stage than during any other period of development. Numerous parasitic and predaceous insects destroy a great many eggs and this is especially true where the eggs are concentrated upon certain plants, as in the case of corn used as a trap crop. A tiny parasite, scarcely visible to the unaided eye, is responsible for the destruction of from 20 to 80 per cent of the eggs laid upon corn, as well as a large percentage of those upon cotton. Numerous insects feed largely upon bollworm eggs and small larvæ; the larvæ of several ladybirds and small larvæ known as aphid lions are among those most beneficial in this respect.

The larger bollworm larvæ are preyed upon by several insects, among the more important of which are several species of wasps and ground beetles. The value of the common black and red wasps which so frequently build nests in trees and outhouses near cotton fields is unquestionable. At Paris, Tex., during 1905, a nest of the former species, located in an old cotton house with several cotton fields near by, was carefully observed for two hours. The nest consisted of about 800 cells, with about 280 adults present at one time. During the period of examination 168 wasps entered with food for their larvæ and for other adults. In 118 instances the food brought in was recognized as being bollworm larvæ. Probably the majority of the other 50 wasps carried bollworms, but identification was impossible, because the larvæ were so badly mangled.

Several large robber flies, so often seen in cotton fields, and a few species of spiders, have been known to capture bollworm moths. The common toad also is beneficial, for in several instances the writers and others have found numerous bollworm larvæ in its stomach.

There are published few records of birds feeding upon bollworms, yet there is every reason to believe that bollworm larvæ and adults are destroyed by many species. Domestic fowls are undoubtedly valuable in reducing the number of bollworms on cotton located near houses and barns. Several instances have come under the writers' observation in which cotton adjacent to barns where chickens, turkeys, and guineas were kept was practically free from bollworms, while at some distance out in the fields the injury was quite severe.

One of the most important checks upon bollworm increase is the cannibalistic habit of the larvæ themselves. After the larvæ have attained considerable size they are ever ready to engage in battle with their fellows whenever they chance to meet. When two larvæ are of unequal size the smaller is usually killed and devoured by its fellow, but if their size is about the same, both larvæ often die as a result of injuries inflicted upon each other. This factor is of greatest importance in corn, for if all of the larvæ hatching in the silks of an ear should attain full growth nearly every ear would be completely destroyed. The reduction in bollworm numbers in ears of corn, due mainly to this cause, is illustrated by the following figures: During August, 1905, 10 ears of corn were examined just after the silks began dying, and 198 larvæ in all stages of development were found. This gives an average of 20 larvæ per ear, most of which were small, or about 10 times the number which would ultimately reach maturity. Cannibalism is a less important factor among larvæ on cotton, as in that case the larvæ are more generally distributed over the plants and therefore meet less frequently.

A certain bacterial disease is worthy of note as an important natural factor in bollworm control. As a rule the disease develops among the larger larvæ and a larger percentage of larvæ usually die in corn ears than upon cotton; this is probably due to the fact that more moisture is present in the corn ears than in the small fruit of cotton where the larvæ feed. From 2 to 50 per cent of larvæ taken on corn and cotton and kept in the laboratory have been found to die of this disease. Examination of several thousand ears of corn during July showed that from 1 to 5 per cent of the larvæ found therein had succumbed to this disease.

RECOMMENDATIONS.

The investigations conducted by the Bureau of Entomology during the past three years show that by the general adoption of the several means of control herein described losses from the bollworm may be largely prevented, even during years of severe injury.

The fact that bollworms do not become numerous in cotton until the hardening of the early corn about August 1 is the basis for the recommendation of certain cultural methods not only advantageous in the presence of the bollworm and boll weevil, but desirable practices in cotton growing regardless of insect enemies. These methods are as follows:

(1) Thorough plowing of the land during the fall and winter. This operation is not only the means of destroying many bollworm pupæ, but is of importance from an agricultural standpoint, in exposing the soil to the actions of rain and frost, thus helping to break up its constituents and render them more readily dissolved and consequently available for plant food. Fall plowing is also a requisite for early planting.

(2) The use of early fruiting varieties of cotton.

(3) The use of fertilizers to hasten and increase fruit production.

(4) Planting the crop as early in the spring as practicable.

(5) Early and frequent chopping and cultivations.

Along with the improved farm practices above outlined, the cotton crop may be materially protected by the use of corn and cowpeas as a trap crop (as described on pages 18-19). That the greatest benefit may be derived from the use of the trap crop system it is urged that each farmer in a neighborhood plant at least a few acres of June corn and cowpeas about the 1st of June.

The use of arsenical poisons upon the cotton will be found of value in proportion to the severity of bollworm attack. Paris green is recommended at the rate of about 3 pounds per acre, applied in the dust form, either pure or diluted with lime or flour. Application by

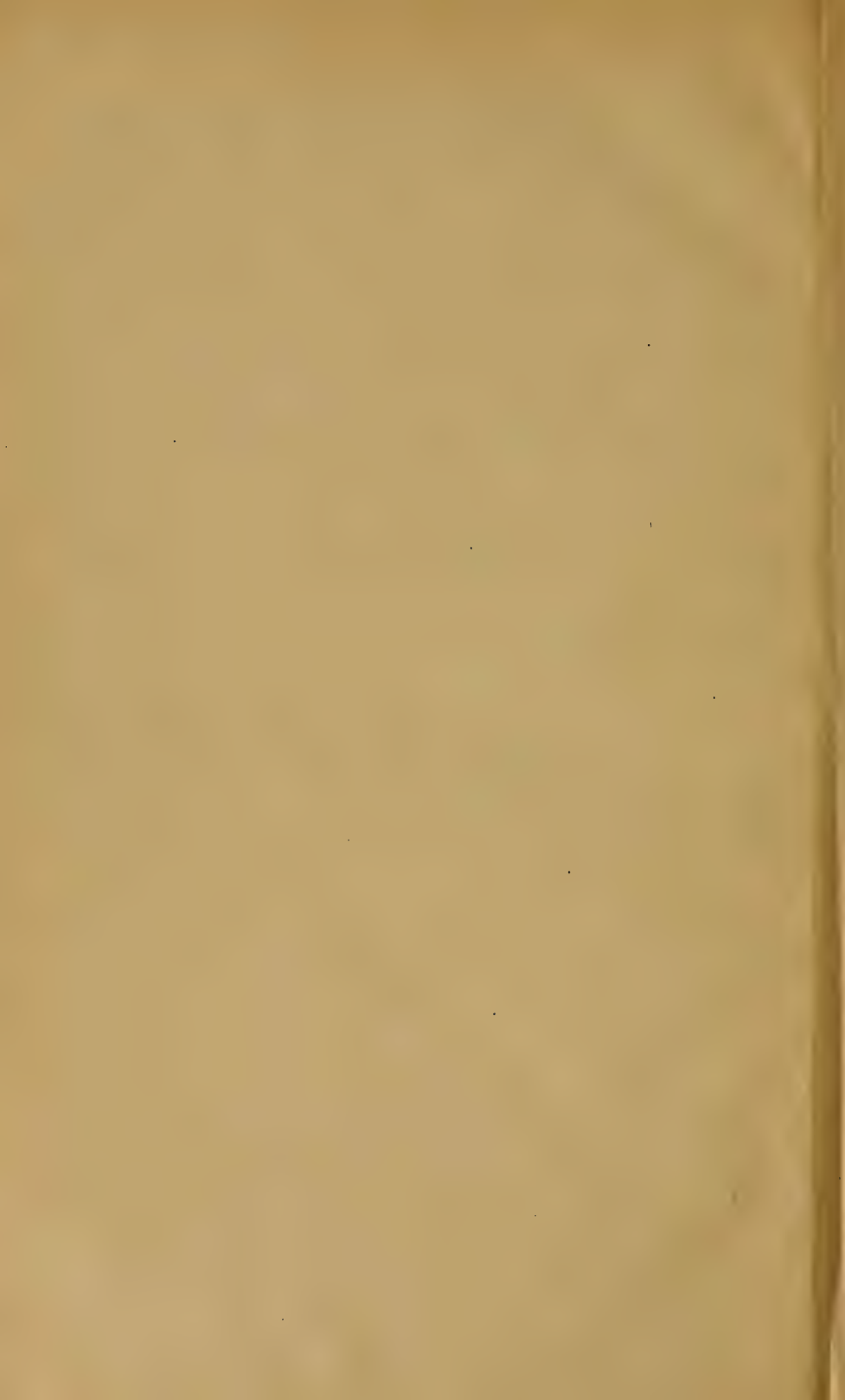
either the bag and pole method or by geared machinery is satisfactory. The work should be done when the plants are moist with dew or after a light shower. Two applications, when not followed immediately by rains, should be sufficient; the first should be made when the eggs begin to hatch in numbers, usually between July 25 and August 5; this may be followed by a second in about one week. If rains follow the applications, these should be repeated immediately.

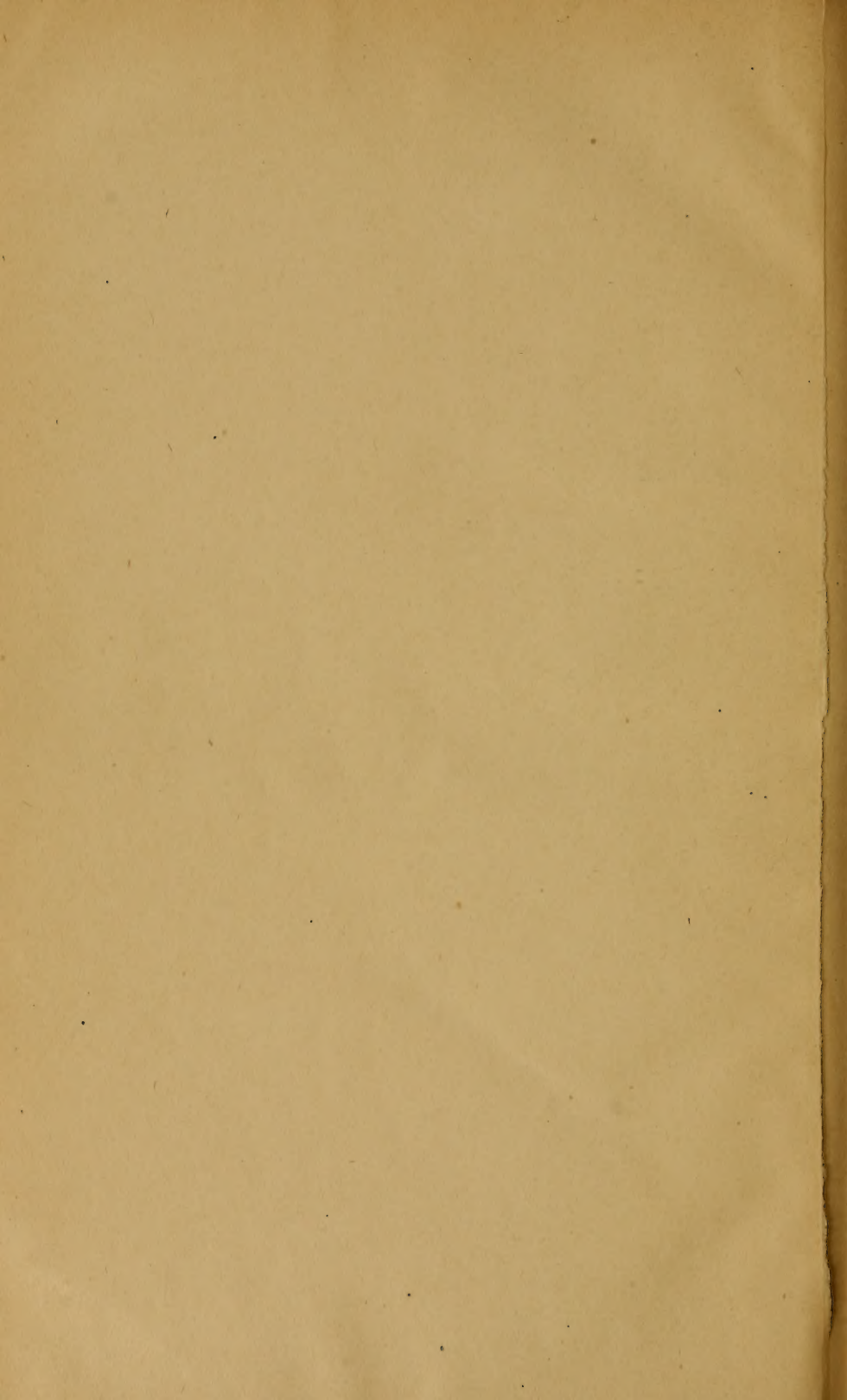
Destruction of the early generations of bollworm larvæ in corn seems impracticable, except in certain cases of isolated areas and where the acreage of corn is small as compared with that of cotton.

Owing to the great value of wasps in destroying bollworm larvæ throughout the season a protest should be made against the common practice of destroying their nests. Where domestic fowls are reared these should be encouraged to feed as much as possible in adjoining cotton.

For practical as well as other reasons wild birds should be protected and encouraged in their visits to cotton fields.









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